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SOCIETAL CONSEQUENCES OF TITLE II OF PUBLIC LAW 92-513: "MOTOR VEHICLE INFORMATION AND COST SAVINGS ACT"

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16. Abstract

Societal consequences of the availability, under Title II, Public Law 92-513, of information on crashworthiness, crash repair cost, routine maintenance and repair cost, and insurance cost are investigated. Surveys of small groups of private passenger car buyers and fleet buyers were conducted, and the results were analyzed. Three simple computer models were prepared: (1) an Accident Model to compare the number of occupants suffering fatal or serious injuries under assumed car-buying behavior with and without the availability of Title II information and changes made by car manufacturers which modify crashworthiness and car weight; (2) a New Car Sales Model to determine the impact of car-buying behavior on 22 societal elements involving consumer expenditures and employment, sales margin, and value added for dealers, car manufacturers, and industrial suppliers; and (3) a Car Operations Model to determine the impact of car-buying behavior on the total gasoline consumption cost, crash repair cost, routine maintenance and repair cost, and insurance cost. Projections of car-buying behavior over a 10-year period (1976-1985) were made and results presented in the form of 10-year average values of the percent difference between results under "with Title II" and "without Title II" information.

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EXECUTIVE SUMMARY

Title II of Public Law 92-513, the *Motor Vehicle Information and Cost Savings Act*, requires that information on

- The damage susceptibility of passenger motor vehicles,
- Their crashworthiness,
- The ease of diagnosis and repair of mechanical and electrical systems which may fail during use or which may be damaged in crashes,

and at a later date,

- Differences in insurance cost between makes and models based upon differences in the first two characteristics listed above,

be provided to the car buying public.

The original objective of this study was to determine the societal consequences of alternative ways to implement the requirements of Title II. Alternatives are available in terms of:

- Which aspects of the characteristics are to be quantified,
- Which measures are to be used for these quantifications,
- Context(s) in which the information is presented for comparisons,
- The way(s) of presenting the information, and
- The way(s) of disseminating the information.

Early in the study, the emphasis was changed by NHTSA. Alternatives as outlined above were no longer to be considered by CEM but those which appeared to be the most likely ones to be implemented were selected. The objective then became the estimation of the consequences of implementing the selected combination of alternatives.

The following consequences were considered:

- Changes in the sales of new cars, and the corresponding consequences upon the car buying public, dealers, manufacturers and their suppliers;
- Changes in the numbers of fatal or seriously injured passenger car occupants, resulting from a changing automobile population;
- Changes in the cost of crash repairs, of mechanical and electrical repairs, and gasoline consumption resulting from a change in the vehicle population.

The problem was approached in the following steps:

Step 1: The reaction of potential automobile buyers to Title II information was studied.

Step 2: The potential technological and economic reactions of manufacturers were assessed.

Step 3: A model was developed to calculate the effects of changes in new car sales on future traffic fatalities and serious injuries.

Step 4: A model was developed to calculate the consequences of changes in new car sales in terms of total expenditures, employment, sales margin, and value added associated with dealers, manufacturers, and the most important suppliers of materials.

Step 5: A model was developed which allowed calculation of the impact of a change in new vehicle sales upon the vehicle population and consequently upon the cost of repairing and maintaining cars, of repairing crash damage and upon gasoline consumption.

Step 6: Scenarios were developed, making various alternative assumptions on the behavior of consumers and manufacturers.

Step 7: Computer models were applied to the scenarios and the consequences calculated.

The results of these steps are as follows:

Step 1: Potential automobile buyers were administered questionnaires in two field studies. The main conclusions were that subjects given Title II information tended to buy larger, more crashworthy cars than others. Crashworthiness appeared to be the most important of the Title II characteristics; the cost of routine repair and maintenance cost was of lower importance; and crash repair and insurance cost was of little concern. These results should be interpreted with great caution, however, because the subjects were, on the average, better educated and had higher incomes than the typical new car buyer.

Also, the managers of nine automobile fleets were contacted. Due to the small sample size, only tentative conclusions may be drawn. They are that the economic aspects are of prime importance to fleet buyers. Information on crashworthiness will be considered by some, and some are even willing to pay more for more crashworthy cars.

Step 2: We found considerable engineering knowledge of potential crashworthiness improvements, compatible with current automobile production processes. There exists, however, only extremely sketchy information on how these improvements would numerically reduce the occupants' injury and fatality risks.

Considering the conclusion of Step 1 that buyers might shift to larger cars as a consequence of having Title II information, domestic manufacturers would have no incentive to improve the crashworthiness of their cars, because increased sales of larger cars provide greater profits to manufacturers. Also, since crash repair cost appears to be of little importance to buyers, manufacturers have no incentive to reduce crash repair cost. There exists, however, the possibility that repair and maintenance cost may be reduced for competitive reasons.

Step 3: At NHTSA's specific request, a simple accident model was developed. It assumes that the number of accident-involved cars is proportional to the number of registered passenger cars, and that the fatality or injury risk for car occupants depends primarily on the characteristics of the car. To account for interactions with other cars, an overall correction factor based on car weight was developed. Among other things, the model has been used to show that a total shift by consumers to the safest class of cars--full size--would reduce fatal or serious injuries only about one-half as much as total implementation of air bags, which would be much less costly to consumers.

Step 4: The impacts of new car sales in terms of total expenditures, employment, value added or sales margin was determined by car class for the following societal elements:

- Consumers - Basic car cost and cost of options
- Dealers - Employment and sales margin
- Manufacturers - Employment and value added
- Suppliers of steel - Employment and value added
- Suppliers of rubber - Employment and value added
- Suppliers of aluminum - Employment and value added
- Suppliers of plastics - Employment and value added
- Suppliers of paint - Employment and value added
- Suppliers of lead - Employment and value added
- Suppliers of copper - Employment and value added
- Suppliers of glass - Employment and value added

A computer model was developed to calculate the impact of a specific composition of new car sales, by car class, upon these societal elements.

Step 5: Gasoline consumption cost, crash repair cost, and routine maintenance and repair cost were estimated, in relation to VMT and car class. Also, insurance cost was determined using current rate structures. A computer model was developed which, for a given automobile population by age and car class, allowed calculation of the total expenditures for gasoline, crash repairs, maintenance and repairs, and insurance premiums.

Step 6: Once the Accident Model, New Car Sales Model, and Car Operations Model had been satisfactorily checked, a number of scenarios were postulated and their societal consequences were evaluated. Initially, emphasis in analysis was placed on the Accident Model, because it involved the most input parameters:

- Market Share Shifts among car classes as a consequence of the availability of Title II information or other influences such as the high cost and/or shortage of gasoline and/or a weight tax on new cars.
- Improvements in crashworthiness, which manufacturers might implement as a consequence of the availability of Title II information.
- Reductions in weight, which manufacturers might implement to improve the gasoline efficiency of new cars.
- Decrease in new car sales, relative to long-term sales forecasts of the Department of Commerce.

The above characteristics were investigated singly and in combination in the context of fifteen Accident Model scenarios. The most pertinent results are described in Section 5, where it is shown that of all the parameters considered, improvements in crashworthiness have the most beneficial impact on the reduction in fatal or serious injuries to car occupants in a crash. Simple linear mathematical approximations have been developed for grossly estimating the effects on fatal or serious injuries due to changes in crashworthiness, car weight, and market shares.

The New Car Sales Model has as its primary input the market shares of new car sales for the 10-year period: 1976-1985. Using inputs similar to some of those used in the Accident Model scenarios shows that the four industries most sensitive to market share shifts from small cars to large cars (or vice-versa) are plastics suppliers, steel suppliers, car dealers, and car manufacturers, in that order. (Sensitivity is measured in terms of employment, sales margin, or value added.) These are followed, in order of decreasing sensitivity, by the suppliers of rubber, paint, aluminum, copper, glass, and lead. Other details of the New Car Sales Model are discussed in Section 6.

The Car Operations Model, too, has market shares during 1976-1985 as its primary input. It was found that total gasoline consumption is most sensitive to market share shifts between classes of cars, increasing (or decreasing) by a factor of about five times faster than the cost of routine maintenance and repair and more than 10 times faster than insurance costs. The cost of crash repair is negatively correlated with shifts to larger, generally

more expensive cars to operate, because present experience indicates that when small cars crash with large cars, the small car sustains significantly more damage. Should there be a dramatic future shift to small cars (possibly because of a gasoline shortage), we would expect to see some change in this characteristic. These points are discussed in greater detail in Section 7.

Step 7: Computer models process numbers; scenarios are the verbal descriptions that give meaning to numbers and convert them from data to information. The computer models are (as is often said) no better than the assumptions used in their development. Within the context of this caveat, the most significant results stemming from the computer model investigations of scenarios are:

- No societal elements will be significantly influenced by small market share shifts (ten percent or less) due to the availability of Title II information. There are no societal elements for which the ratio of "% change in the societal element/% market share shift" is greater than unity. In many instances the ratio is of the order of a few tenths or much less.

- Fatal or serious injuries incurred by car occupants in crashes are most significantly reduced by improvements in crashworthiness. This may, therefore, be a fruitful area for emphasis when presenting Title II information.

- Private car buyers will be more influenced by crashworthiness information than any other Title II information and, according to our results, they prefer to be presented crashworthiness information in the form of simple numbers: for example, "4 fatally or seriously injured occupants per 100 crashes." Safety-conscious private car buyers will be influenced to buy larger cars because (under today's manufacturing conditions) they are significantly more crashworthy.

- Cost-conscious private car buyers will be more influenced by the relative cost of gasoline consumption than by any other operational societal element item, because this cost is much more sensitive to car weight. Cost-conscious private car buyers will be influenced to buy a small car.

In summary, the results of this study suggest that possibly the most beneficial aspect of Title II information may be in influencing car manufacturers to improve the crashworthiness of small cars. Private and fleet car buyers may be primarily influenced to buy small cars because of events outside the scope of Title II: the high cost of gasoline and/or a shortage of gasoline and/or a tax on new cars by weight. The secondary influences of the availa-

bility of Title II information on operational costs and crashworthiness which assist a buyer in choosing the "best" car within a weight class will be useful, but will have little overall impact on the societal elements considered in this study. Only major market share shifts (e.g., from large cars to small cars) will have a significant impact on the societal elements considered herein. For other than crashworthiness, we judge on the basis of the results developed in this study that extra-Title II events will have much more impact on societal elements than will the availability of Title II information.

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Mr. Horace Wuerdemann carried out the Fleet Buyers Study, with assistance from Ms. Kayla Costenoble. Mr. Henry Mlynarski and Dr. Richard Greenfield assisted in the early phases of this study. Mr. Joseph Reidy developed the coefficients for the 22 societal elements in the New Car Sales Model and performed many other analytical tasks. Mr. John Ball programmed the models and used them to perform more than 200 computer analyses of scenarios. Other CEM staff contributing to the preparation of this report include Ms. Teri Mayer, Mrs. Carmela Miller, Mrs. Hattie Vince, and Mrs. Marjorie Wallace.

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1.0 INTRODUCTION

1.1 Background

Title II of Public Law 92-513, the *Motor Vehicle Information and Cost Saving Act*, requires that the Secretary of Transportation investigate methods to determine the following characteristics of passenger motor vehicles:

(1) The damage susceptibility of such vehicles;

(2) The degree of crashworthiness of such vehicles;

(3) The characteristics of such vehicles with respect to the ease of diagnosis and repair of mechanical and electrical systems which fail during use or which fail during use or which are damaged in motor vehicle accidents.

The Secretary has to devise specific ways for disseminating such information, and present it to the public in a simple and readily understandable form in order to facilitate comparisons between the various makes and models of passenger motor vehicles with regard to the characteristics listed above.

At a later date, automobile dealers are required to distribute to prospective purchasers information developed by the Secretary which compares differences in insurance cost for different makes and models of passenger motor vehicles based upon differences in damage susceptibility and crashworthiness.

To obtain information on the full range of beneficial and adverse consequences of Title II on various affected groups, a study has been directed to predict the outcomes resulting from an assumed implementation of Title II. This report describes the results of the study, performed under Contract No. DOT-HS-4-00887.

1.2 Objectives of the Study

The study objectives are:

(1) To predict specific economic-sociological, environmental, political, safety and other consequences resulting from alternative ways of implementing Title II of the "Motor Vehicle Information and Cost Savings Act,"

(2) To identify and describe significant socio-economic, environmental, safety and other trade-offs among the various alternatives,

(3) To predict the net societal benefits or losses resulting from the implementation of selected alternative methods.

The study objectives were achieved in the following steps:

- Estimating how consumers change their automobile purchase patterns as a result of providing them with Title II information in a certain way, with the consequence that the mix of new cars sold will change, and possibly new cars offered will be different.
- Developing models which allow estimation of how changes in the mix of new cars sold will affect injuries, fatalities and property damages in crashes, and other repair cost.
- Developing models which estimate overall societal effects resulting from changes in new car sales, automobile repair cost, and crash damage and injuries.
- For alternative ways of presenting Title II information, estimating changes in new car sales, the resulting changes in crash damage, etc., and the consequent societal effects.

1.3 Outline of the Report

The results of the study are discussed in Section 2. The conceptual approach for the conduct of the study is given in Section 3. The events and influencing factors which cause changes in the characteristics of the automobile population are presented in Section 4.

Section 5 outlines the simple Accident Model used in this study, and describes the results of sensitivity analyses, using the model. The New Car Sales Model and the 22 societal elements which comprise it are described in Section 6. The four societal elements of the Car Operations Model are presented in Section 7.

The general role of scenarios in this study is explained in Section 8, which includes results for four extreme scenarios that involve total market share shifts to single classes of cars. A small number of more realistic scenarios is analyzed in detail in Section 9.

The appendices contain support information from the study, such as references, details of the private consumer study and the brief fleet buyers study, and the data bases for the three societal consequences models.

2.0 RESULTS OF THE STUDY

2.1 Areas of Investigation

Study results of significance were obtained from the following research areas:

- The Private Consumer Study
- The Fleet Buyers Study
- Development and use of the Accident Model
- Development and use of the New Car Sales Model
- Development and use of the Car Operations Model
- Synthesis and analysis of scenarios

Results from each of the study areas are discussed below.

2.2 The Private Consumer Study

Results of the Private Consumer Study* are based on responses from 280 private car buyers, most of whom were Federal employees. One-fifth of the group received no Title II information; the rest did. From analyses of the returns, the following results were obtained:

- Preferences for specific automobiles depend most on age, income, and the product of age and income. Using these variables, regression equations were developed for buyer ratings of cars for which Title II information was provided.
- Title II information on crashworthiness had the greatest impact on the preferences of car buyers. They tended to prefer cars that were more crashworthy.
- Because collision insurance generally covers most of the cost of crash repair, respondents were not much influenced by this Title II information.
- Response to Title II information on routine maintenance and repair was mildly positive.
- Response to Title II information on insurance rates indicated this information was of little concern to participants.
- In response to various ways of presenting Title II information (in brochures about cars), participants preferred simple numbers, rather than graphs, bar charts, etc.
- In their response to Title II information on crashworthiness, participants showed a small, but definite, trend to buy larger, safer cars, with fewer options. In general, participants exposed to Title II information spent about 10% more for a car, primarily to buy a larger, more crashworthy car.

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*See Section 4 and Appendix B.

2.3 The Fleet Buyers Study

Response to questionnaires were obtained from nine vehicle fleet buyers* (fleets purchase between 10 to 20% of the automobile production in each year).The buyers represented two municipal governments, three utilities, and four private companies. There were about 19,000 cars in the fleets repr sented by these buyers. Analysis of the returned questionnaires provided the following:

- The distribution of about 7100 cars purchased in 1974 by these nine buyers was:
  - Subcompact: 5%
  - Compact: 20%
  - Intermediate: 60%
  - Full Size: 15%
- In planning purchases of 1975 cars (without Title II information), about three-fourths of the buyers expected to change their purchase volume:
  - Half of the buyers will buy about one-half as many cars in 1975, versus 1974 purchases.
  - A fourth of the buyers will buy about 30 percent more cars in 1975, relative to 1974 purchases.
  - Half the buyers will buy smaller cars because of the increased price of vehicles and gasoline.
  - About 6000 1975 cars will be purchased by these buyers, a reduction of 16 percent, compared to 1974.
  - Relative to 1974 purchases, the buyers will obtain:
    - -- the same number of subcompacts
    - -- 18% more compacts
    - -- 11% less intermediates
    - -- 88% less full size cars
- When given theoretical Title II information, the fleet buyers responded as follows:
  - For typical compact car buyers (7 responses):
    - -- 30% would stay with same make and model
    - -- 70% would shift to car with a better Title II rating
    - -- None would shift down to subcompacts
  - For typical intermediate car buyers (8 responses):
    - -- 75% would stay with same make and model
    - -- 12.5% would shift to most crashworthy intermediate
    - -- 12.5% would shift to a full size car
- When purchasing cars, the information sources used most frequently by the buyers are, in order of priority:
  - Manufacturers brochures
  - "Official" used car buying guides (Blue Book)
  - Own maintenance and repair personnel
  - Personal buying experience

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*See Appendix G.

- Preferred car features, ranked by the buyers, are:

  1. Safety and protection of occupants.
  2. Car price; gas economy; reliability.
  3. Availability and quality of service; vehicle responsiveness.
  4. Dealer reputation.
  5. Manufacturer's warranty.
  6. Brand name reputation; resale or trade-in value.
  7. Solidness of construction.
  8. Roominess; power and pickup; styling and appearance.
  9. Riding comfort.
  10. Prestige.

2.4 Development and Use of the Accident Model

The simple Accident Model used in this study (see Section 5) has six inputs:

- Number of registered cars of model year 1975 and before.
- Number of registered cars in 1976 through 1985, by model year.
- Market shares for 16 cars (or, 4 car classes) for 1975 and before, and 1976 to 1985.
- Car weight for 16 cars (or, 4 car classes) for 1975 and before, and 1976 to 1985.
- Risk factors* for 16 cars (or, 4 car classes) for 1975 and before, and 1976 to 1985.
- Crash probabilities† for 1975 through 1985.

The output of the model used for the study is the 10-year average value of fatal or serious injuries (FOSI) to car occupants averted due to the availability of Title II information.

In developing and determining the sensitivity of this Accident Model, the following results were noted:

- The output of the model (10-year average of FOSI averted) is most sensitive to changes in Risk Factor. These factors lie in the range 0.075 to 0.035 in this study. Implementation of air bag restraints would reduce Risk Factors by about 40-50%, in turn resulting in about 25% FOSI averted (10-year average). The possibility of this significant change may influence car manufacturers to turn to air bags as a way of improving their Title II crashworthiness ratings.
- The availability of Title II information on crashworthiness may result in car buyers purchasing larger, more crashworthy cars. If all buyers purchased only full size cars for the next 10 years, there would be about 15 percent FOSI averted (10-year average), i.e., significantly less than would derive from implementation of air bags.

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*Risk Factor is defined to be the conditional probability of a fatal or serious injury to a car occupant, given that the car is in a reportable crash.

†Crash probability (the probability that a registered passenger car will be in a reportable accident at least once during a calendar year) was assumed to be 0.10 throughout this study.

- The model is not very sensitive to Market Share Shifts* from one car class to another. For example, a 10 percent Market Share Shift from small cars to large cars results in only about one percent FOSI averted (10-year average). Conversely, a 10 percent Market Share Shift from large cars to small cars (possibly due to a gasoline shortage) would increase FOSI incurred by about one percent.
- The model is not highly sensitive to small changes in car weight. For example, each 10 percent reduction in average weight of all new cars results in about 2 percent FOSI averted (10-year average). If average weight increases by that amount, then about 2 percent additional FOSI are incurred.

2.5 Development and Use of the New Car Sales Model

The primary input to the New Car Sales Model (see Section 6) is Market Shares for 1975 (and Before) through 1985. The model outputs are percentage changes (10-year average) for 22 societal elements involving cost to consumers for cars and options, employment and sales margin for car dealers, and employment and value added for car manufacturers and seven major industrial suppliers. In developing the coefficients for the societal elements we found:

- Employment is essentially independent of car weight for car dealers, car manufacturers, and that portion of the lead industry supplying the auto industry. Therefore, Market Share Shifts have essentially no impact on these societal elements.
- Dealers' sales margin increases exponentially with weight. Value added increases essentially linearly† with weight for car manufacturers and all suppliers. Therefore, a Market Share Shift to larger cars for increased crashworthiness will result in a general increase in sales margin and value added throughout the automobile industry. Conversely, a Market Share Shift to small cars will have a negative impact on these societal measures. The supply industries most affected are steel and rubber.
- The societal elements change less than one-half percent (10-year average) for each one percent change in Market Shares. We conclude, therefore, that the 22 societal elements are not highly sensitive to small changes in Market Shares.

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*A 10 percent Market Share Shift involves taking 5 percent of the market from one sector and giving that 5 percent to another sector.

†A linear increase with weight was assumed, based on the meager amount of data available. We expect a more detailed analysis would not significantly change the results discussed here.

2.6 Development and Use of the Car Operations Model

The principal input parameter for the Car Operations Model (see Section 7) is also Market Shares for 1975 (and Before) through 1985. The model outputs are percentage changes (10-year average) for four societal elements: (1) cost of gasoline consumption; (2) cost of crash repair; (3) cost of routine maintenance and repair; and (4) cost of insurance. In developing and exercising this model, the following results were obtained:

- The cost of gasoline consumption is most sensitive to Market Share Shifts, increasing about 0.17 percent (10-year average) for each percent increase in Market Share Shift to large cars. Changes in the other three societal elements are less by a factor of four or more.
- In this model, the cost of crash repair is negatively correlated with increase in weight. This occurs because, historically, when small cars have crashed with large cars, they have usually sustained much more damage. (If buyers were to shift to small cars entirely, this trend should change some, but it would take at least a decade for the present large car population to diminish significantly.)
- As Market Share Shifts take place, the cost of routine maintenance and repair changes at a rate that is one-fifth the rate of change of gasoline consumption cost. The rate of change of insurance cost is less than one-tenth that for gasoline consumption cost. We conclude, therefore, that of the four societal elements considered in this model, the availability of Title II information would have a significant impact only on the cost of gasoline consumption. This would be particularly pertinent at present, because a significant Market Share Shift to large cars for crashworthiness would eventually increase gasoline consumption several percent. During the coming decade, we expect that there will be strong efforts to curb gas consumption, rather than increase it.*

2.7 Synthesis and Analysis of Scenarios

Investigation of scenarios took place in three stages. Fifteen scenarios were considered in conducting sensitivity analyses with the Accident Model (see Section 5). Next, four extreme scenarios were investigated to essentially determine the bounds of the "solution space" within which answers for more plausible scenarios would be found (see Section 8). Finally, four scenarios were considered in detail in Section 9.

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*Of course, if people buy larger cars and drive less to hold down gasoline consumption, then even more FOSI will be averted.

The results from the Accident Model sensitivity analyses are given in Section 2.4, above.

The four extreme scenarios involved the impact of buyers purchasing only one of the four car classes throughout the next ten years. The results, *according to these models*, are as follows:

- If car buyers shifted completely to all full size cars, we would have (all 10-year average values):
  - A 15 percent increase in FOSI averted
  - A 14 percent increase in gasoline consumption cost
  - A 6 percent increase in routine maintenance and repair
  - Consumers paying 38 percent more for basic cars
  - Consumers spending 35 percent less for options (because many are included in the basic cost of a full size car)
  - A 52 percent increase in car dealers' sales margin
  - A 14 percent increase in employment by car manufacturers, and a 37 percent increase in value added
  - An increase of 15 to 50 percent in employment in supply industries and a 17 to 61 percent increase in value added.
- If car buyers shifted completely to subcompacts,and all the cars were produced in the U.S.*, we would have (all 10-year average values):
  - A 14 percent increase in FOSI incurred
  - A 28 percent decrease in gasoline consumption
  - An 8 percent increase in cost of crash repair
  - A loss of 43 percent in dealers' sales margin
  - A decrease of 22 percent in manufacturers employment, and a decrease of 28 percent in value added
  - A decrease of 22 to 33 percent in suppliers employment, and a decrease of 29 to 43 percent in value added.

Of course, the above conditions are virtually certain <u>not</u> to occur, but it is of interest to have estimates of what would happen, if they did.

In Section 9, four far more realistic scenarios were investigated in which Market Share Shifts ranged between 20 percent up to large cars to 20 percent down to small cars. Both abrupt and gradual changes over four years were considered. (Gradual changes in Market Shares further diminish their impact on the various societal elements.) Within these bounds the general nature of results was (all 10-year average values):

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*At present, only about one-half of the subcompacts sold in the U.S. are produced here.

- The change in percent FOSI averted stayed within ± 3 percent, if no changes were made in crashworthiness and weight, and within 20 to 30 percent if significant improvements were made in those parameters.
- Changes in gasoline consumption cost were within ± 4 percent; crash repair cost within about ± 1 percent; routine maintenance and repair within ± 0.8 percent; and insurance cost within about ± 0.3 percent.
- Changes in employment by manufacturers and suppliers were within about ± 7 percent; changes in value added were within about ± 10 percent. Changes in consumer expenditures were within ± 4 percent for basic car cost and ± 3 percent for options.

3.0 CONCEPTUAL APPROACH

3.1 Objectives

The original objectives of the study were to:

(1) Predict specific economic-sociological, environmental, political, safety and other consequences resulting from alternative ways of implementing Title II of the *Motor Vehicle Information and Costs Savings Act;*

(2) Identify and describe significant socio-economic, environmental, safety and other trade-offs among the various alternatives;

(3) Predict the net societal benefits or losses resulting from the implementation of selected alternative methods.

A plan to achieve these objectives was developed by CEM in a previous study.* This resulted in the following objectives for this second phase of the study.

(1) Estimate how consumers may change their automobile purchase patterns as a result of providing them with Title II information in certain alternative ways, and how manufacturers might respond to such changes.

(2) Develop models which will allow the estimation of how changes in the mix of new cars sold will affect injuries, fatalities and property damage in crashes, and other repair costs.

(3) Develop models which will estimate overall societal effects resulting from changes in new car sales, automobile repair cost, and crash damage and injuries.

(4) For alternative ways of providing Title II information, estimate changes in new car sales, the resulting changes in crash damage, etc. and the consequent societal effects.

During the course of the study, the emphasis was changed in response to interactions with NHTSA. The main change was that no alternative ways of implementing Title II were considered. Rather, emphasis was placed on applying the model to alternative assumptions of the reactions to Title II information by car buyers and manufacturers.

*H.C. Joksch, *CEM Report 4150-495, Predicting Societal Benefits and Costs Resulting from the Implementation of Title II of PL-92-513. Study Design. Phase I,* The Center for the Environment and Man, Inc., August 1973.

3.2 The Structure of the Problem

3.2.1 Quantifying and Disseminating Title II Information

Title II defines the information to be disseminated only in very general terms, namely:

(1) Damage susceptibility

(2) Crashworthiness

(3) Characteristics...with respect to the ease of diagnosis and repair of mechanical and electrical systems which fail during use or which are damaged in motor vehicle accidents.

What the numerical or categorized expressions of this information are depends on:

- Which characteristics are measured,
- Under which conditions are they measured,
- What units of measurement are used.

Alternative ways of dealing with these basic questions can result in quite different quantifications of Title II information.

Damage Susceptibility.

For any given car, crash damage to it depends at least on:

- Type of crash - rollover, collision with a fixed object, with another vehicle, or a combination of these events;
- Impact speed (or speed when the vehicle began to turn over);
- Impact site;
- Impact direction;
- Weight(s) of other car(s) and/or object(s) hit;
- Shape of other car(s) and/or object(s) hit;
- Energy-absorbing characteristics of other car(s) and/or object(s) hit.

Therefore, if damage susceptibility of different cars is to be compared, differences in the influence of the factors listed above have to be eliminated. The simplest way of doing this would be to compare damage under standardized conditions, e.g., barrier crashes at certain speeds. The results of such standardized crashes, however, might not be representative for the damage suffered in real, more complicated crash situations. If one is using real accident experience, the problem is that critically important information, such as speed, is not reliably available, if available at all. State accident records contain only extremely gross estimates of property damage, if any, insurance records which contain actual cost information contain usually only very little information on crash factors.

Only at first glance does the dollar amount of damage repair cost appear to be a natural measure of damage susceptibility. Another important aspect is whether a car can, after a crash, be safely driven away under its own power or whether it has to be towed at additional cost and delay. Also, the time it takes to have a car repaired (possibly including time to wair for repair parts) can be an important consideration; in some cases it can be more important to have a car quickly repaired than to save on repair cost.

Even if one accepts the dollar cost of repairs as an adequate measure, the question arises as to how it is to be determined. In many cases, a question of judgment arises as to whether to straighten or to replace sheet-metal parts, or whether to use new or used replacement parts. Thus, repair cost for a given damage are not always unambiguously defined. This is even more the case when the damage is severe and a decision has to be made whether to repair the damage or to replace the car. Another question at the other end of the severity scale is: when is a damage "no damage" for practical purposes? Some owners might not have small damages repaired because they are not bothered by them, others might not repair them because they do not think it worth the cost and the trouble.

This leads us to the question: What measure of damage susceptibility is important to the buyer of the car? If he carries collision insurance, under the current rate structure, the total cost of damage to be expected below his deductible limit appears to be the most relevant measure; this will be different if insurance cost should reflect make/model differences in damage susceptibility.

Thus, damage susceptibility is a characteristic which can be quantified in various plausible alternative ways.

Crashworthiness

Crashworthiness describes the protection from injury or death a car offers a car's occupants in a crash. The deceleration pattern an occupant suffers in a crash, sharp objects in the car which he might hit, the strength of the occupant compartment providing space for the occupants are all elements of crashworthiness. Some of them can be quantified objectively. Important, but much less objective measures are the probabilities of death or certain types of injuries.

Again, the severity of a crash in terms of forces acting on an occupant and injuries suffered by him depends on many factors; those listed above under damage susceptibility and others, such as:

- Ejection
- Separation of the windshield
- Age of the victim
- Occurrence of fire.

To compare cars with regard to their crashworthiness, one has to eliminate the influence of such factors. Again, the simplest way to do this is to compare standardized crashes, such as barrier crashes at prescribed speeds. Such tests give physical measurements such as deceleration patterns and compartment deformations. They do not directly give injury and fatality risks; these may only be calculated with considerable uncertainty.

Comparing the results of standardized test crashes may not necessarily give a realistic picture of the overall crashworthiness of a car. If, e.g., one car practically never turns over, its crashworthiness in such a situation is of little importance, compared with a car which may fairly often turn over. Direct information on the frequency of injury and death can be obtained only by analyzing actual crashes. The difficulties of obtaining meaningful, not even "accurate" or "reliable," information from actual crash records are well known. There is selectivity in crash reporting, subjective evaluation of the severity of injuries, inaccuracies in the data reported, and, on top of all this, insufficient knowledge to quantitatively control for the influence of all factors known to have an influence on injury severity.

Thus, any estimate of crashworthiness is subject to considerable uncertainty (and this might be less for the common car types with a large data base than for low volume cars). This uncertainty is just as important a part of the measurement as the best estimate itself. Comparing the frequency of fatal injuries might reveal great differences between cars. Comparing the frequencies of non-fatal injuries is likely to result in much smaller differences. For many users the less severe, but much more likely injuries might appear more important than the rare fatal injuries.

Another important question is the context of making comparisons: comparing cars under high speed, limited access highway traffic conditions might be irrelevant for an urban commuter (and vice versa).

Finally, comparisons between cars with belted drivers might (but do not necessarily have to) give different results than comparing the same cars with unbelted drivers. Thus, a result applicable to belt users may be irrelevant for non-users, and vice versa.

In sum, the problem of measuring crashworthiness, in addition to the practical problems, is conceptually even more difficult than to measure damage susceptibility.

<u>Ease of Diagnosis and Repair</u>

The mechanical and electrical maintenance has for a car owner the following aspects:

- The frequency and cost of scheduled maintenance services;
- The frequency and cost of repairs due to manufacturing defects;
- The frequency and cost of repair due to deterioration;
- The frequency and cost of repairs due to sudden failures;
- The frequency and cost of repairs due to crash damage.

Though it appears relatively easy to compare the ease of diagnosis and repair of certain defects, assuming a mechanic of average competence with the equipment suggested by the manufacturer, it is more difficult to utilize this information in a way meaningful to the consumer. Complicated diagnosis and expensive repairs might be acceptable if this is compensated by very infrequent needs for them. Even more, a high degree of reliability against sudden failure might justify much higher cost of diagnosis and repair for many buyers.

Again, as in the case of crashworthiness, it might not be possible to find one measure which will satisfy all car buyers' requirements; however, it might be possible to find a measure which reflects the needs of a large segment of the buying population.

<u>Insurance Cost Information</u>

A basic difficulty with automobile insurance is that a policy covers a car (or several cars) and all of its drivers, and the policy holder (and members of his family) and all cars he drives. Thus, there is no simple relation between the premiums paid on the basis of a policy and any single car (or a set of cars).

In the past, the following types of automobile insurance were sold:

- Liability - personal injury
  property damage
- Auto medical
- Collision
- Comprehensive

Liability insurance cost does not depend on any of the Title II characteristics of the insured car. It primarily depends on the driver's characteristics. If at all, there is a discount for compact cars, because they cause less damage to third parties and their vehicles.

Auto-medical insurance premiums also currently do not depend on the insured car, though the loss experience should depend on the crashworthiness of cars used by the policy holder. Collision insurance premiums depend primarily on the purchase price and age of the car; again, the loss experience should be influenced by damage susceptibility of all cars used by the policy holder ("Bumper discounts" are an example of this.)

Comprehensive coverage is against theft and damage by fire, unrelated to accidents and wind-storm. Its premium also depends upon purchase price and age of the car.

Some states have now replaced the liability insurance by a combination of liability and no-fault insurance. This provides coverage for certain medical cost and wage losses to the policy holders, but still maintains his right to certain liability claims against a third party. Currently, no-fault premiums do not reflect Title II characteristics, presumably due to the large influence of the liability component.

Thus, current insurance premiums do not reflect differences in Title II characteristics.

3.2.2 Reactions of Car Buyers and Manufacturers

There are many factors which can, and do in various ways influence a consumer's choice. Title II information will be in addition to it. Usually consumers will have to make a tradeoff between selecting a "better"--with regard to Title II--car and other desired car attributes. Not even Title II information is likely to unambiguously identify "better" cars--one can expect that a buyer will have to make a tradeoff between crashworthiness and repair and maintenance cost.

It is possible by market research techniques to study the current reaction of consumers to Title II information. The reaction in the future will change, be it just due to the regular availability of Title II information for a longer period, or due to DOT campaigns aimed at increasing the utilization of Title II information by the public.

Whereas consumers can react in only one way to Title II information, manufacturers have several options. The simplest option is to "do nothing" and adjust production volume to changing demand. This might be the preferred short term reaction for manufacturers for whose cars the demand increases, or when the shift is from less profitable to more profitable cars. Manufacturers whose cars sell less because of Title II information may attempt to improve the relevant characteristics. To what extent this is possible depends on the engineering knowledge as to what are the necessary changes, and what are the cost implications of such changes. It is conceivable, however, that these manufacturers will modify their advertising and sales strategy as to counteract unfavorable Title II ratings. On an overall basis, manufacturers might attempt to change consumers' attitudes towards Title II information, possibly emphasizing some and deprecating the importance of others. It is conceivable that some manufacturers use "good" Title II ratings of their cars aggressively in advertising. It is even conceivable that a manufacturer may improve his cars' Title II characteristics if this can be done without too high cost.

Finally, there is the possibility that manufacturers develop and publish their own measures of Title II characteristics to counter the effects of DOT's ratings (similar to the publication of gas mileage figures by manufacturers measured in a manner different from EPA's).

A special problem arises for manufacturers whose cars might not be rated due to too small a volume. It is extremely difficult to predict what would happen to sales of such cars. These manufacturers could develop their own "Title II" characteristics and use them in a competitive manner.

3.2.3 Accident Modeling

To predict the effects of a change in market shares and Title II characteristics upon traffic accidents, injuries and deaths, one needs a model determining:

(1) The change in the composition of the automobile population in terms of types and model years;

(2) The number of accidents occurring;

(3) The interactions of different cars--if any--in accidents;

(4) The occurrence of death or injury in accidents.

Questions (1), (3) and (4) have been addressed by CEM in a previous study* and answered, according to the current state of the knowledge. To answer Question (2) is beyond the current state of the art because there is no universally accepted definition of what constitutes an accident, and operational definitions differ between states and probably change over time. Therefore, to make realistic predictions of the number of deaths or injuries in traffic accidents, indirect approaches, avoiding the concept of the "accident" have to be used.

3.2.4 Societal Consequences

Changing the market shares and possibly physical properties of new cars has two types of consequences:

(1) The immediate consequences, related to the production and distribution of cars, and

(2) The long-term consequences resulting from the use of cars over their entire lifespan.

Immediate consequences of car purchases are sales for manufacturers and dealers, demand for parts, materials, energy and services, and the corresponding employment. These effects occur simultaneously with the purchase--at most with a few months delay. Some of the effects of changes in purchases may be net effects, e.g., shifts to heavier cars using more materials, others may have little, if any, net effect, e.g., shift from one make to another.

Long-term effects of car use are gasoline consumption (and consequent air pollution), demand for service, repair, replacement parts and insurance coverage. They will depend to some extent on the use, to some extent on the age of the cars. Again, some effects of Title II may be net effects, e.g., a change in gasoline consumption due to a shift to heavier cars. Others may have little net effect, e.g., a shift to more crashworthy cars, if they are neither heavier nor more expensive to repair. The redistribution effects, however, could be major, even if the net effects are small.

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*H. C. Joksch, *An Accident Trend Model*, CEM Report 4148-510, Contract DOT-HS-246-3-670, August 1974.

3.2.5 Scenarios

When estimating the effects of Title II, one has to make a comparison of a development expected when Title II is implemented with one which would have occurred without Title II. The effects might be quite different, depending upon what would have happened without Title II. For example, if there would be a trend towards smaller cars in the future, Title II might have a much greater impact compared with a situation where the trend would have been towards larger cars. Therefore, one has to develop scenarios, "What would happen without Title II," as a basis for assessing its effects.

3.3 The Approach to the Problem

The elements discussed in Section 3.2 and their interrelations were put in an overall relation to each other as shown in Figure 3-1. Then, smaller elements, their relation in more specific terms, and a logical sequence were developed, as shown in Figure 3-2. This structure served as an outline for approaching the problem. It was modified as needed during the conduct of the work.

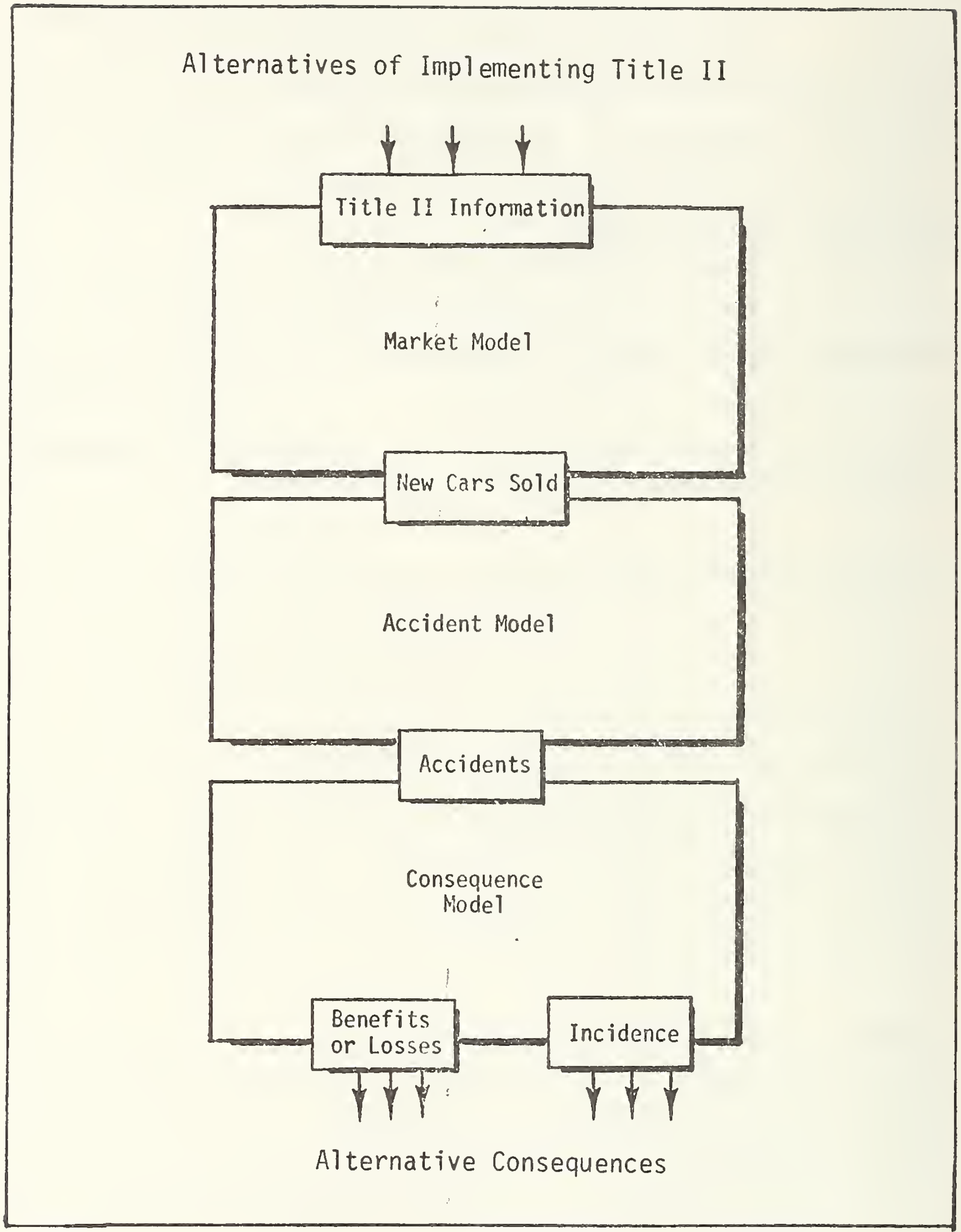

Figure 3-1. The overall approach to the problem.

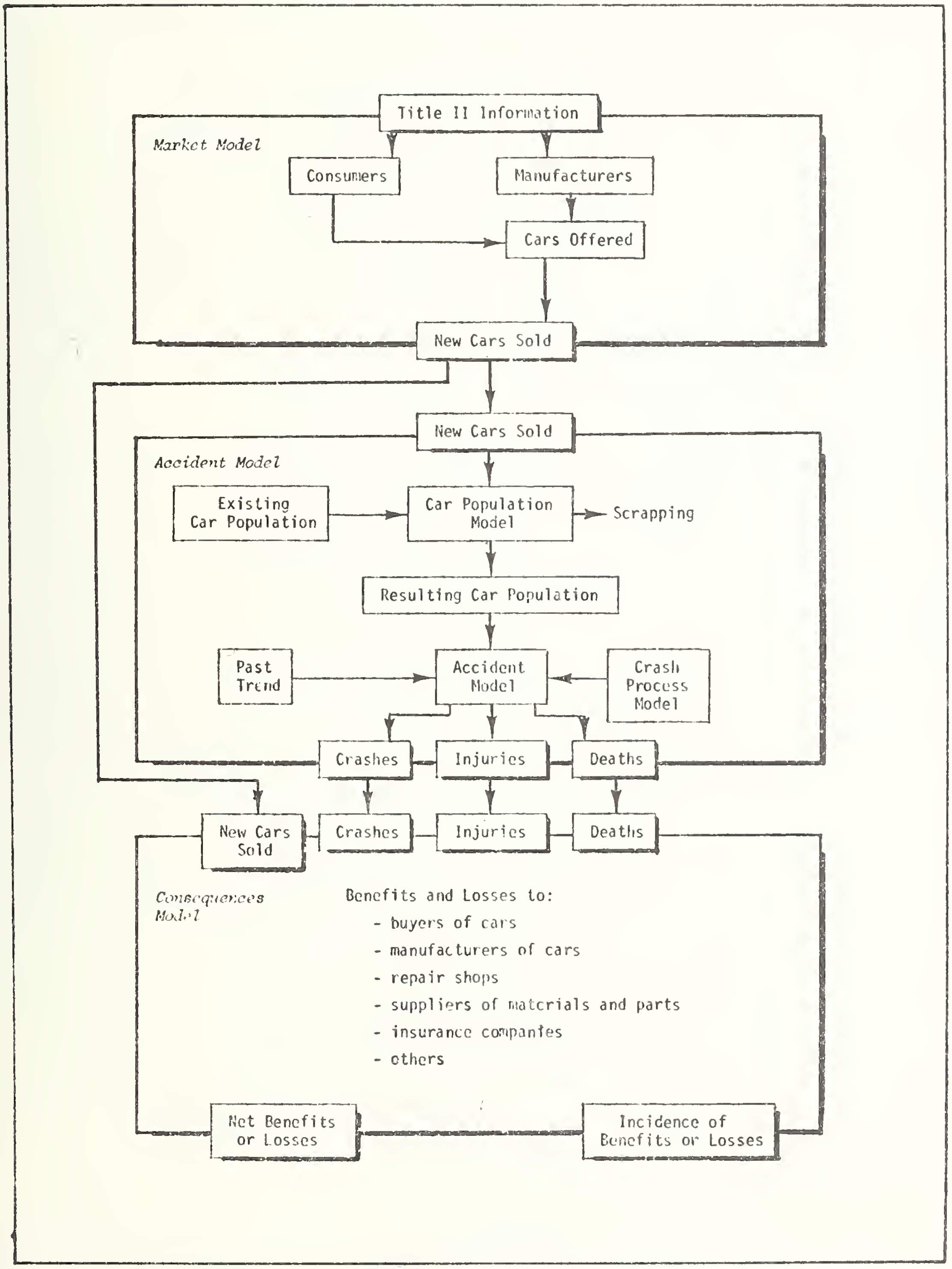

Figure 3-2. The detailed approach to the problem.

4.0 CHANGES IN THE CHARACTERISTICS OF THE AUTOMOBILE POPULATION

4.1 General

Changes in the characteristics of the automobile population take place in the following ways:

1) Existing cars leave the population (being scrapped or exported).
2) Consumers buy cars in proportions different from those in the existing population.
3) Manufacturers offer different cars.

The first aspect has been extensively studied previously by CEM.* We found that the "survival" function of cars by age changed over time, in a not directly explainable pattern; and we made tentative projections of this function up to 1985. We took a second look at survival of cars by manufacturer. There were some indications of differences, but no pattern. This is not surprising, since manufacturers make a wide range of models. Model-by-model information, however, was not available. Therefore, we assumed survival of the existing automobile population corresponding to the function previously derived.

Changes in the automobile population resulting from changed consumer behavior and potential changes in cars which might be made by manufacturers are discussed in the following two sections.

4.2 Market Shares for 16 Hypothetical Cars: Results from the Private Consumer Study

4.2.1 Management of the Survey

The Licensed Driver Survey was conducted by two testing groups: Burke Marketing Research and U.S. Testing. The Burke sample involved 151 persons; U.S. Testing had 129 respondents.

One-fifth of each group was a "control group." They received no Title II information.

Respondents in each group were given pamphlets describing the characteristics of 16 hypothetical cars. There were four cars in each of four basic classes as shown in Table 4-1.

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* H.C. Joksch, *CEM Report 4135-496, Evaluation of Motor Vehicle Safety Standards*, The Center for the Environment and Man, Inc., September 1973.

TABLE 4-1

BASIC CAR CLASSES AND WEIGHTS

Class	"Name"	Curb Weight (lb)
Sub-Compact	Bat Alba Chee-Sai Mini	2539 2300 2250 1970
Compact	Gnome Musketeer Beacon Libra	2745 2950 3292 3215
Inter-mediate	Diadem Oriole Machete Aladdin	3685 3681 3925 3825
Full Size	Condor Hastings Taurus Ocelot	4400 4341 4469 4800

4.2.2 Description of Data Taking

Burke and U.S. Testing divided their groups into five equal subgroups, as indicated in Table 4-2 below. Each group was provided information on the 16 hypothetical cars; however, the four subgroups which received Title II information were also given "real" or "distorted" Title II data.

TABLE 4-2

CAR INFORMATION PROVIDED FOR SUBGROUPS

Subgroup	Information Provided for Each Car		
	Page 1	Page 2	Page 3
1 (Control)	Standard Features	• Options • Fuel Economy	• Evaluation
2	(Same)	• Options • Fuel Economy • Insurance Cost	• Evaluation • "Real" Title II data in table format
3	(Same)	(Same as above)	• Evaluation • "Distorted" Title II data in table format
4	(Same)	(Same as above)	• Evaluation • "Real" Title II data in graph format
5	(Same	(Same as above)	• Evaluation • "Distorted" Title II data in graph format

For development of preferences for the 16 cars, the four subgroups which received Title II information were combined. Therefore, the Market Shares information described below is based on:

- "Before Title II" Results - 20% of Group (i.e., 56 respondents)
- "After Title II" Results - 80% of Group (i.e., 224 respondents).

4.2.3 Data Analysis

Data analysis consisted of:

- Basic tabulations of results,
- One-variable linear regressions,
- Selected multi-variable linear regressions.

After preliminary analysis had been conducted, it was concluded that buyer preference for each of the 16 cars was best expressed by the following regression equation:

$$\begin{aligned}\text{Buyer Rating for Car } i &= \left[a_i + b_i \times \begin{pmatrix}\text{Age}\\ \text{Index}\end{pmatrix} + c_i \times \begin{pmatrix}\text{Income}\\ \text{Index}\end{pmatrix} + d_i \times \begin{pmatrix}\text{Age}\\ \text{Index} \end{pmatrix} \times \begin{pmatrix}\text{Income}\\ \text{Index}\end{pmatrix}\right] \\ &+ \left[e_i + f_i \times \begin{pmatrix}\text{Age}\\ \text{Index}\end{pmatrix} + g_i \times \begin{pmatrix}\text{Income}\\ \text{Index}\end{pmatrix} + h_i \times \begin{pmatrix}\text{Age}\\ \text{Index}\end{pmatrix} \times \begin{pmatrix}\text{Income}\\ \text{Index}\end{pmatrix}\right] \times [0 \text{ or } 1] \\ &= [\text{Term A}] + [\text{Term B}] \times [0 \text{ or } 1]\end{aligned}$$

Inclusion or exclusion of Term B depends on whether Title II information was provided ["1"], or was not given ["0"]. The Age Index varied from 1 to 6, and the Income Index varied from 1 to 8. The relationships of the indices to ages and incomes are given in Table 4-3 below.

TABLE 4-3

INDICES FOR AGE AND INCOME

Age		Income	
Index	Years	Index	Annual Income ($ thousands)
1	Less than 25	1	Less than 5
2	25 through 34	2	5 to 7.5
3	35 through 44	3	7.5 to 10
4	45 through 54	4	10 to 15
5	55 through 64	5	15 to 20
6	65 and older	6	20 to 25
		7	25 to 30
		8	30 and more

The regression equations were calculated in a stepwise fashion, entering variables one by one in decreasing order of importance. The regression coefficients of that step were selected which gave the lowest error of the calculated values. Tables 4-4 and 4-5 show the non-zero coefficients used to determine Buyer Ratings.

TABLE 4-4

REGRESSION EQUATION COEFFICIENTS FOR BUYER PREFERENCES
(Burke Data; 151 Respondents)

Class	Hypothetical Car	Title II Information Not Provided				Title II Information Provided			
		Constant (a_i)	Age Coeff. (b_i)	Income Coeff. (c_i)	(Age) (Income) Product (d_i)	Constant (e_i)	Age Coeff. (f_i)	Income Coeff. (g_i)	(Age) (Income) Product (h_i)
Sub-Compact	1. Bat	1.42				0.23	-0.16		
	2. Alba	1.71							-0.02
	3. Chee-Sai	2.73	-0.28						-0.02
	4. Mini	2.12			-0.06				
Compact	5. Gnome	2.89	-0.42						
	6. Musketeer	4.26	-2.10	-0.40	0.35	0.58	0.41		-0.10
	7. Beacon	4.29	-1.02	-0.37	0.15			-0.01	-0.02
	8. Libra	2.74	-0.41			0.26			
Inter-mediate	9. Diadem	2.88	-0.36						
	10. Oriole	2.49	-0.38						
	11. Machete	2.73	-0.32						
	12. Aladdin	2.26			-0.04				
Full Size	13. Condor	1.43				-0.24	0.14		
	14. Hastings	1.31			0.03				
	15. Taurus	1.07					0.08		
	16. Ocelot	2.29	-0.38					-0.06	0.04

TABLE 4-5

REGRESSION EQUATION COEFFICIENTS FOR BUYER PREFERENCES
(U. S. Testing Data; 129 Respondents)

Class	Hypothetical Car	Title II Information Not Provided				Title II Information Provided			
		Constant (a_i)	Age Coeff. (b_i)	Income Coeff. (c_i)	(Age) (Income) Product (d_i)	Constant (e_i)	Age Coeff. (f_i)	Income Coeff. (g_i)	(Age) (Income) Product (h_i)
Sub-Compact	1. Bat	1.61	0.48		-0.1		-0.26		0.05
	2. Alba	3.76		-0.43	0.02	-0.65	-0.09	0.14	
	3. Chee-Sai	2.54		-0.11					
	4. Mini	2.51		-0.14					
Compact	5. Gnome	2.73		-0.13			-0.04		
	6. Musketeer	2.73							
	7. Beacon	2.59		-0.16					-0.02
	8. Libra	2.79							-0.02
Inter-mediate	9. Diadem	2.70	0.13	-0.15					
	10. Oriole	2.19		-0.08					
	11. Machete	2.06				0.10			
	12. Aladdin	2.27		-0.05					
Full Size	13. Condor	1.44		0.09					
	14. Hastings	1.27	0.67	0.55	-0.12	0.60		-0.08	
	15. Taurus	0.34		0.30			0.35		-0.06
	16. Ocelot	-0.08		0.43		0.32			-0.05

The Buyer Ratings, once computed from the regression equations, comprised thirty-two 6 x 8 age-income matrices. That is, there are two 6 x 8 age-income matrices for each of the 16 cars. One matrix is for the "Without Title II Information" condition; the other is for the "With Title II Information" condition.

Each of these 32 matrices was multiplied by a 6 x 8 age-income matrix which gives new car sales distribution (for 1000 cars).* This matrix is shown in Table 4-6. The 48 matrix product elements were then summed and normalized to give the Market Shares, for the With and Without Title II Information conditions, for the 16 hypothetical cars.

TABLE 4-6

NEW CAR SALES DISTRIBUTION BY AGE AND INCOME
(1000 Cars)

Annual Income ($1,000's)	(Age (years))						Total
	Less than 25	25 thru 34	35 thru 44	45 thru 54	55 thru 64	65 and Older	
Less than 5	11.55	3.08	1.54	3.08	2.31	7.7	29.26
5 to 7.5	19.25	18.94	9.24	6.16	12.32	17.71	83.62
7.5 to 10	26.95	38.50	19.25	19.25	12.32	17.71	133.98
10 to 15	26.95	50.05	40.81	42.35	27.72	6.16	194.04
15 to 20	19.25	40.04	46.20	54.67	37.73	6.16	204.05
20 to 25	12.32	26.95	40.04	54.67	40.81	6.93	181.72
25 to 30	4.62	16.94	32.34	40.81	32.34	6.93	133.98
30 or more	0	3.0	12.0	14.0	10.0	3.0	43.00
Total	120.89	197.5	20.142	234.99	175.55	72.3	1002.65

*Updated from a table given by F. Linden, "Profiling the New Car Market," in *The Conference Board Record*, February 1969. See Appendix C.

4.2.4 Market Model Results

Evaluation of the two sets of 16 regression equations for the Burke and U.S. Testing data provides the results shown in Figures 4-1 and 4-2.

In both instances, the results indicate a general shift on the part of consumers from smaller to larger cars, as a consequence of the availability of Title II information.

Figures 4-3 and 4-4 show the shift from and to car classes. Both the Burke and U.S. Testing results further indicate the trend from small to large cars, due to the availability of Title II information.

Table 4-7 summarizes all data presented in Figures 4-1 through 4-4.

The reader will note that the "Hastings" (a Full Size car) appears to have the largest Market Share of all cars, in both the Burke and U.S. Testing results. This point was briefly investigated. In the brochures given to respondents, among the Full Size cars the "Hastings" was:

- Second from the best in Crashworthiness
- Most expensive in Damage Repair cost
- In the middle of the Ease of Diagnosis and Repair Range
- At the top of the range (best) in Average Miles/Gallon
- At the bottom of the range (best) in Fuel Cost for 10,000 miles of Driving
- At the middle of the range for Insurance Premium Discount from Basic Rate
- Second most expensive of the four Full Size Cars.

These features alone do not appear to offer compelling reasons why the "Hastings" was apparently the most desirable car of the 16. It is possible that the "Madison Avenue" descriptions which introduced each car's characteristics were the motivating element. Consider the lead statements for each car, and keep in mind that the whole sales "pitch" for each car tended to amplify the theme of the lead statement. Statements are given in the order presented in the brochure.

- TAURUS - *"Tough - but beautiful. That's TAURUS."*
- OCELOT - *"This full size beauty is no pussy cat."*
- HASTINGS - *"The regal HASTINGS truly deserves to be called King-of-the-Road."*
- CONDOR - *"This is the one the little guys have to watch out for!"*

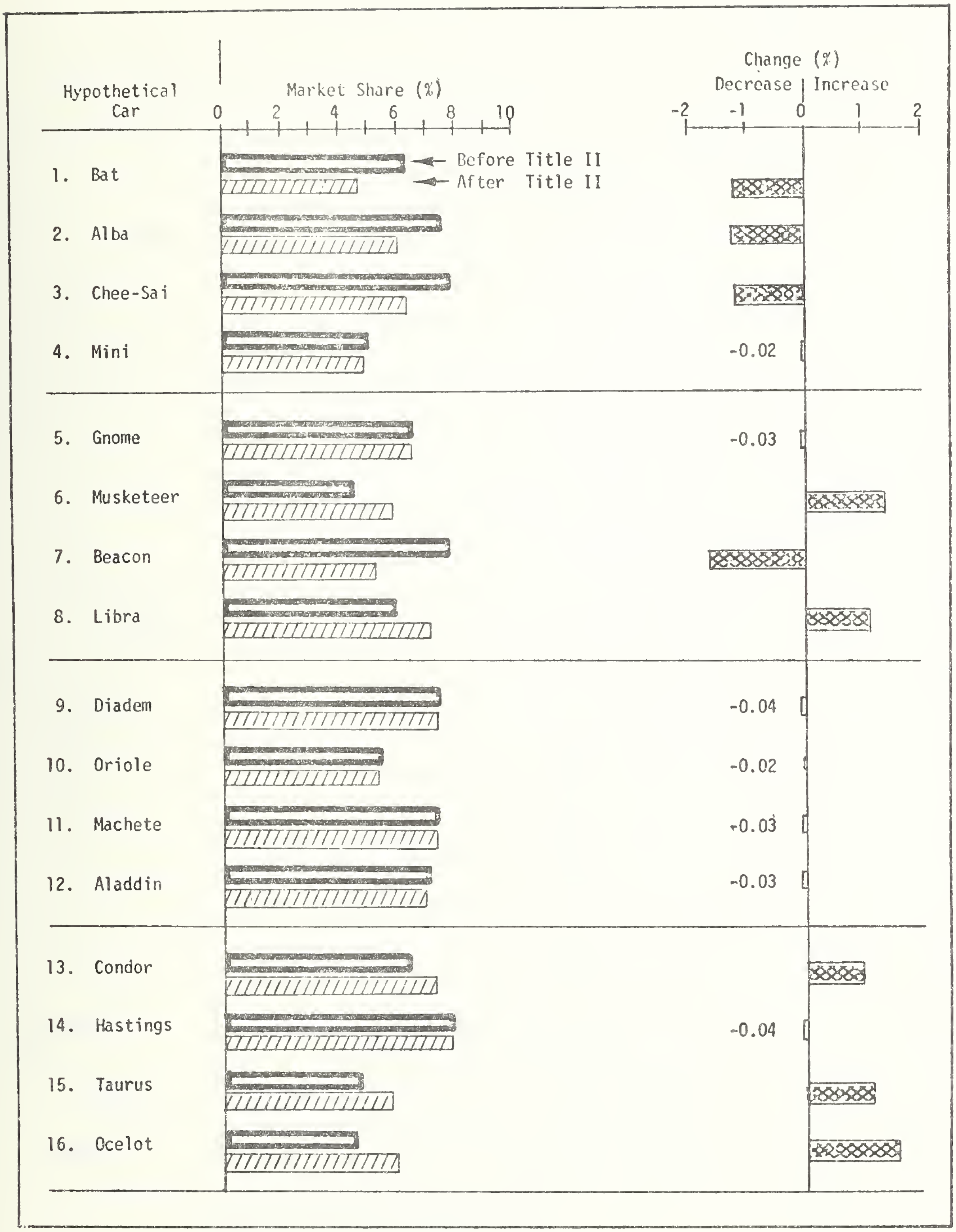

Figure 4-1. Market shift results from the Licensed Driver Survey (Burke).

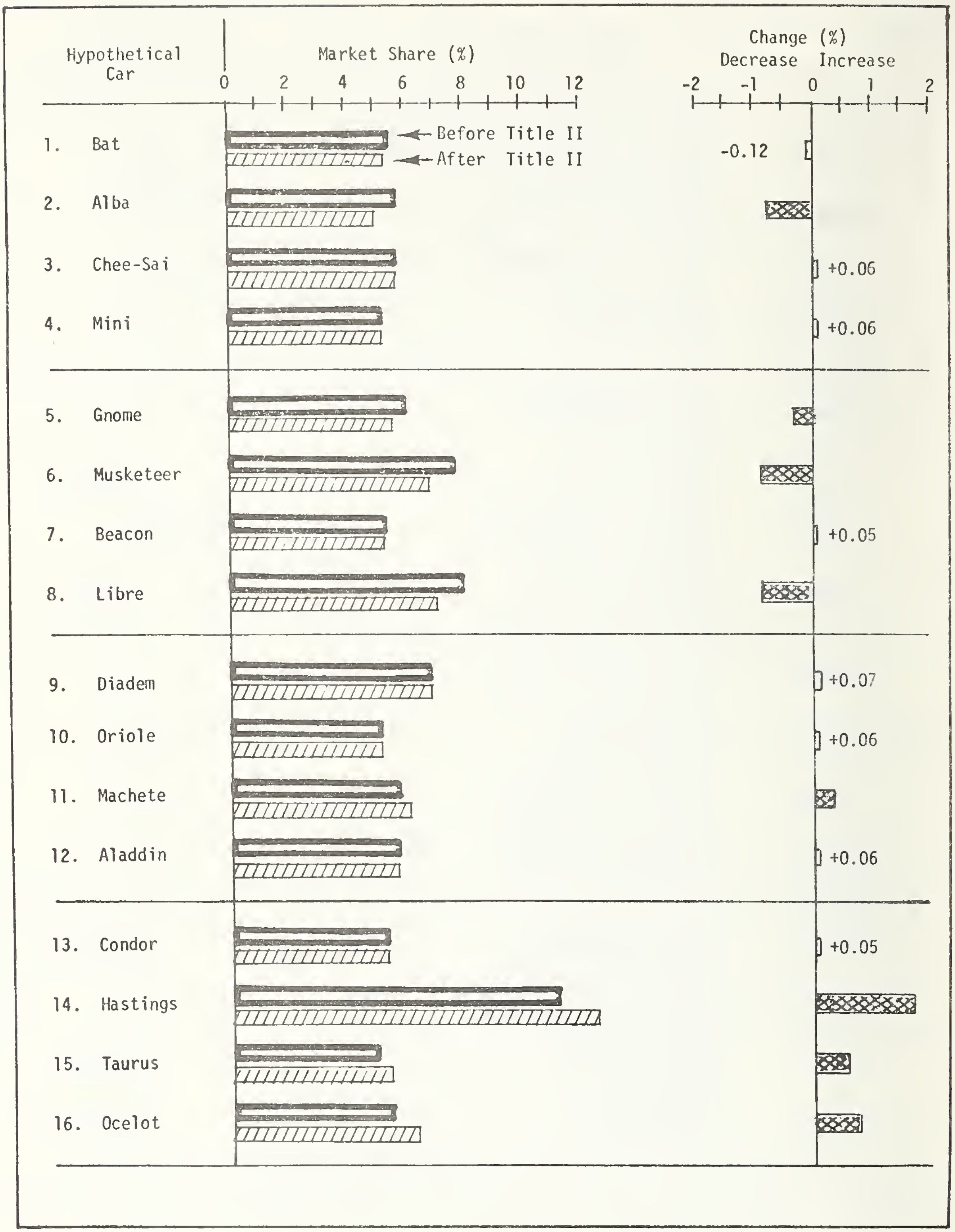

Figure 4-2. Market shift results from the Licensed Driver Survey (U. S. Testing).

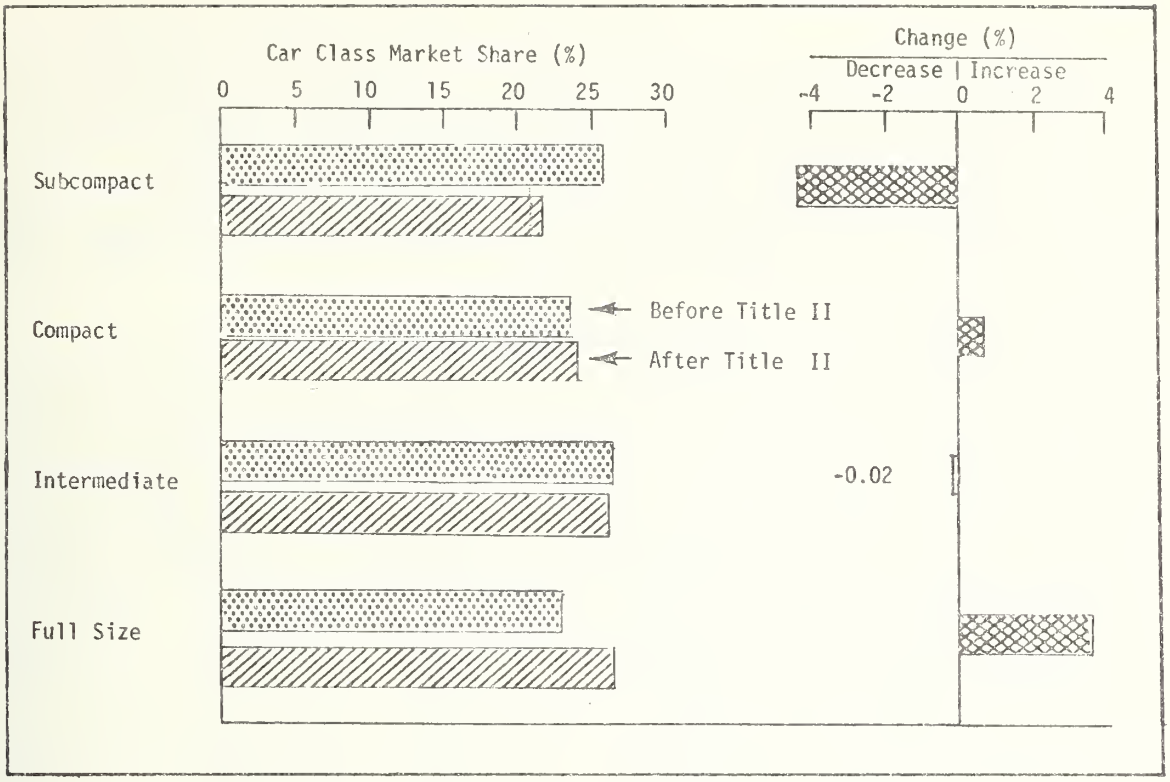

Figure 4-3. Market shifts among car classes (Burke).

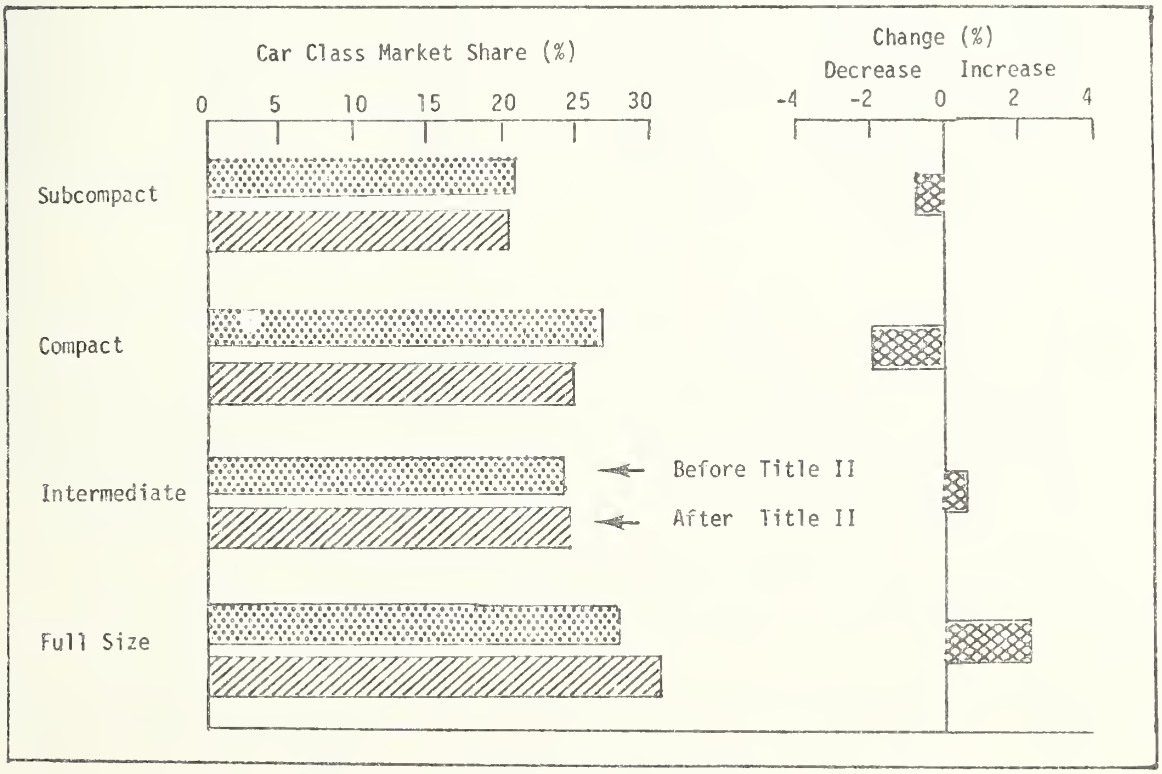

Figure 4-4. Market shifts among car classes (U.S. Testing).

It is suggested that emotional appeal in response to advertising may be one of the compelling factors in establishing market shares in this survey. In short, in choosing a new car, perhaps many people like the thought of being "King-of-the-Road" when they are behind the wheel of their car.

TABLE 4-7

MARKET MODEL RESULTS

Class	"Name"	Market Shares			
		Burke Results		U. S. Testing Results	
		Without Title II Information	With Title II Information	Without Title II Information	With Title II Information
Sub-Compact	Bat	0.0619	0.0483	0.0453	0.0441
	Alba	0.0746	0.0600	0.0583	0.0506
	Chee-Sai	0.0780	0.0634	0.0576	0.0582
	Mini	0.0496	0.0494	0.0526	0.0532
Compact	Gnome	0.0644	0.0641	0.0603	0.0470
	Musketeer	0.0448	0.0585	0.0779	0.0693
	Beacon	0.0679	0.0513	0.0522	0.0527
	Libra	0.0593	0.0703	0.0796	0.0710
Inter-mediate	Diadem	0.0728	0.0724	0.0692	0.0699
	Oriole	0.0528	0.0526	0.0516	0.0522
	Machete	0.0721	0.0718	0.0588	0.0623
	Aladdin	0.0700	0.0697	0.0580	0.0586
Full Size	Condor	0.0624	0.0721	0.0533	0.0538
	Hastings	0.0786	0.0782	0.1190	0.1266
	Taurus	0.0467	0.0581	0.0504	0.0565
	Ocelot	0.0441	0.0600	0.0560	0.0640
Sub-Compact	All 4 types	0.2641	0.2211	0.2138	0.2061
Compact	All 4 types	0.2364	0.2442	0.2700	0.2500
Inter-mediate	All 4 types	0.2677	0.2665	0.2376	0.2430
Full Size	All 4 types	0.2318	0.2684	0.2787	0.3009

4.3 Potential Crashworthiness Improvements

To estimate the impact of potential crashworthiness improvements of cars of current design (excluding safety vehicles of considerably different design), we contacted the National Highway Traffic Safety Administration (NHTSA) and Naval Research Laboratory (NRL) staff and reviewed the literature listed in Appendix A.

It was found that there exists a considerable body of engineering knowledge on how to modify automobiles of current design by using current manufacturing processes to strengthen the occupant compartment and to improve occupant deceleration patterns in crashes. However, rarely were the effects of these improvements estimated in terms of reduction of injury and fatality frequency. Carter[*] shows the effects of various modifications of automobile structures. His figures show that with such changes and air bags, car occupant fatalities in frontal impacts would be reduced by 70%. Since about 50% of all occupant fatalities occur in frontal impacts,[†] overall occupant fatalities would be reduced by 35%. Air bags and structural design could add 300 lb to the weight of a 4000 lb car.

Alexander, Conrad and Neale[‡] analyze the effects of various structural improvements and improved seatbelts (but no air bag) by computer simulation. They use two highly speculative approaches to estimate the resulting reductions in occupant fatalities. The reductions in frontal impacts are shown in Table 4-8. These estimates are conservative: after adding 5% or 10% to the vehicle weight, the actual improvements made were for frontal and side impacts and for rollover accidents. However, fatalities saved due to improvements

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[*] R. L. Carter, *Passive Protection at 50 mph*, NHTSA, DOT-HS-810-197, May 1972.

[†] Estimated from data in the following:
- H.C. Joksch and H. Wuerdemann, "Estimating the Effect of Crash Phase Injury Countermeasures - I. The Reduction of the Fatality Risk," *Accident Analysis and Prevention, 4*, 1972.
- P.S. Carroll, et al., *Current Information on Frequency of Injury and Deaths by Crash Configuration and Speed*, Final Report UM-HSRT-SA-73-6, 1973.
- National Highway Traffic Safety Administration and Transportation System Center, *Analysis of Effect of Proposed Changes to Passenger Car Requirements of MVSS 208*, August 1974.

[‡] Battelle Columbus Laboratories, *Determination of the Trade-offs Between Safety, Weight, and Cost of Possible Improvements to Vehicle Structure and Restraints*, Report DOT-HS-322-621, Draft, 1974.

TABLE 4-8

FATALITY REDUCTION IN PERCENT FOR AUTOMOBILES OF VARYING WEIGHTS

Added Weight of Improvements	Automobile Weight			
	2000 lb	3000 lb	4000 lb	5000 lb
2.5%	4%	0[a]	14%	4%
5.0%	7%	0[a]	7%	16%

[a]These values are questionable.

for side impacts and rollovers could not be estimated. It was estimated that 4% of the weight increase was for improvements for frontal impacts. Therefore, we assumed the weight increases corresponding to the estimated savings to be 2.5% and 5%. These improvements for frontal impacts do, however, also improve protection in side impacts and rollovers somewhat (personal communication with Mr. Neale). Thus, the estimates shown in Table 4-8 are conservative.

In a joint report,* NHTSA and TSC estimate that the air bag could reduce occupant fatalities by 41% and injuries by 35%, assuming 60% lapbelt usage. These estimates were made when the seatbelt-ignition-interlock was still a requirement of the FMSVV's. Because this requirement has since been rescinded, 60% seatbelt usage appears unrealistically high. Therefore, we modified the NHTSA/TSC estimates and assumed only 20% lapbelt usage, which corresponds approximately to current usage. This reduces fatality savings of the air bag system to 35%. The air bag system adds about 75 lb to the weight of a car.† The effects of this weight increase are well within the limits of other uncertainties of our estimates and will therefore not be considered.

There is a question whether the air bag has different effects in small and in large cars. We assume that there is no difference, for the following

*National Highway Traffic Safety Administration and Transportation Systems Center, *Analysis of Effect of Proposed Changes to Passenger Car Requirements of MVSS 208*, August 1974.

†R. L. Carter, *Passive Protection at 50 mph*, NHTSA, DOT-HS-810-197, May 1972.

reason. The functions of air bags are very similar to that of lap-shoulder belt combinations, and somewhat similar to that of lapbelts alone. Results obtained by the Highway Safety Research Center of the University of North Carolina* show that seatbelts in 1970-1972 model cars reduced severe and fatal driver injury in single-car crashes by 46% in subcompact cars, by 45% in compact cars, and in car-to-car crashes by 37% for both subcompact and full size cars. These figures show that the effects of seatbelts are the same in small and large cars.

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*Insurance Institute for Highway Safety, *Status Report*, Vol. 9, No. 2, January 28, 1974, p. 12.

5.0 THE ACCIDENT MODEL

5.1 Purpose of the Model

Accidents have two quantitative aspects: the frequency with which they occur, and the severity of the accidents occurring. In reality, both aspects are intertwined. What is defined legally as a reportable accident depends on the severity--in terms of injury or dollar amount of damage. Therefore, no national total number of accidents is known (numbers found in the literature are either simple additions of figures using different definitions or estimates of illustrative, but not quantitative, value). Even time series of accidents within any one state are of highly questionable validity, because the basis for accident reporting mav change from one year to the next. Therefore, any model using the concept of "number of accidents" throughout the Nation is either resting on a foundation of questionable value, or it has to use a hypothetical number of accidents, derived from other, better known data.*

Accident severity has two aspects: the damage to the vehicle, and injury to occupants. Both depend on many factors, the most obvious ones being speed, site and direction of impact and the other object (or vehicle) hit, if any (in the case of a rollover no object may be identifiable as being obviously "hit").

Damage to the vehicle is characterized by the "damage susceptibility," for which Title II information is required. There is only very limited information available on how vehicle damage depends on the crash circumstances. Therefore, the best that can be done in a model based on empirical information is to assume a certain average amount of damage per crash. depending only on the model of the vehicle.

The occupant injury risk is characterized by the "crashworthiness" aspect of Title II. Quite a lot is known on how this risk of fatality or serious injury depends on speed, type of crash, and the other vehicle's weight, if any. This detailed information, however, is not available by make and model of vehicle. Therefore, if one wants to assess the impact of make and model difference, the other factors have to be ignored.

In this study, damage susceptibility is measured by the annual cost of crash repairs and is based on projection of the passenger car population and the annual market shares within that population. This aspect of accidents is included in the Car Operations Model, discussed in Section 7.

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*An example of how this can be done is found in the development of "adjusted deaths" used in: *CEM Report 4148-510, an Accident Trend Model*, CEM, August 1974.

The Accident Model used in this study is solely concerned with occupant fatalities and serious injuries. It is the purpose of this model to determine the percentage change in fatal or serious injuries that would occur under various assumptions of car population projection, car characteristics, and market shares for classes and types of cars that might plausibly be expected to occur with or without the availability of Title II information for the buying public.

5.2 Background

The Accident Model used in this study is a simple one, having a basic structure recommended by the NHTSA Automobile Rating Division. More sophisticated models are available*, but were not selected by NHTSA/ARD for use in this investigation, because the emphasis in these sophisticated models was in non-Title II areas.

The basic structure of the Accident Model is given by

$$\begin{bmatrix}\text{Number of} \\ \text{Fatal or} \\ \text{Serious} \\ \text{Injuries} \\ \text{(FOSI)}\end{bmatrix}_{\text{Year } n} = \begin{bmatrix}\text{Total No. of} \\ \text{Registered} \\ \text{Passenger} \\ \text{Cars}\end{bmatrix}_{\text{Year } n} \times \begin{bmatrix}\text{Prob. that a} \\ \text{Registered Car} \\ \text{will be in} \\ \text{a Crash}\end{bmatrix}_{\text{Year } n} \times \begin{bmatrix}\text{Conditional Prob.} \\ \text{of a Fatal or} \\ \text{Serious Injury} \\ \text{Given that a Car} \\ \text{Crashes}\end{bmatrix}_{\text{Year } n}$$

Presently, there are about 100,000,000 passenger cars in the U.S. Approximately one-tenth are involved in crashes every year for which police reports are made.† On the average, there is a Fatal or Serious Injury in about one out of every 20 passenger cars that crash. Thus, to a gross approximation the number of Fatal or Serious Injuries in a year is of the order of:

[100,000,000 cars] x [0.10] x [0.05] = 500,000

The above example is meant to give an approximate feel for the order of magnitude of the numbers involved.

In general, whenever a crash situation occurs, the occupants (driver and passengers) in all involved vehicles encounter the risk of being killed or seriously injured. There is an associated "risk factor" which is defined as the "conditional probability of an occupant's sustaining a Fatal or Serious Injury (FOSI) per crash-involved registered passenger car." Risk factors for various

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*D.F. Mela, "How Safe Can We be in Small Cars?", *Proceedings of the Third International Congress on Automotive Safety,* National Motor Vehicle Safety Advisors Council, July 1974.

H.C. Joksch, *CEM Report 4148-510, An Accident Trend Model,* CEM, August 1974.

†*New York State Accident Facts '74,* N.Y. State Motor Vehicle Accident Records RD-20, July 1974.

types or classes of passenger cars may differ significantly as a function of many variables, some of which are:

- Types of Crash
  - Single vehicle
  - Two-vehicle
  - Multi-vehicle
  - Car-truck
  - Truck-truck
- Size of Vehicle (or, weight)
  - Subcompact
  - Compact
  - Intermediate
  - Full Size
  - Luxury
  - Small truck/van/bus
  - Large truck/van/bus
- Driver capabilities and characteristics
- Time of day
- Type of highway
  - Urban
  - Rural
  - Interstate
- Vehicle speed(s)
- Weather/road conditions

In the Accident Model described herein, it is assumed that Risk Factors are a function only of vehicle size, and size is characterized in the Model as curb weight.

This Model has been structured to accommodate sixteen cars (or less).* The time frame for each run of the Model is 1975 through 1985 (eleven years). The Model assumes that all cars for the 1975 and earlier model years represent one group, known as the "Before Title II" cars. Cars for model years 1976 through 1985 are considered to be the "After Title II" cars.

This Model has been designed to accommodate two conditions, defined as:

- *Without Title II:* It is assumed that the 1975 Weights, Market Shares, and Risk Factors for the 16 cars are maintained constant as the car population grows from about 95 million in 1975 to 138 million in 1985. In short, nothing changes.†

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*Actually, two versions of the Accident Model exist. One uses inputs for 16 cars. The other uses average input for four car classes: Subcompact, Compact, Intermediate, and Full Size cars. The latter model has been exercised the most in this study.

†By a different interpretation of inputs, this Accident Model can be used to produce "Without Title II" results that incorporate any desired changes with time in Market Shares, Car Weights, Risk Factors, and Car Population. However, for the purpose of explaining the basic structure of the Model, we prefer the more concise definitions given.

- *With Title II:* It is assumed that the 1975 (and before) cars comprise the "Before Title II" group of cars, and the 1976 (and later) cars comprise the "After Title II" group of cars.

These conditions are illustrated in Figure 5-1, below.

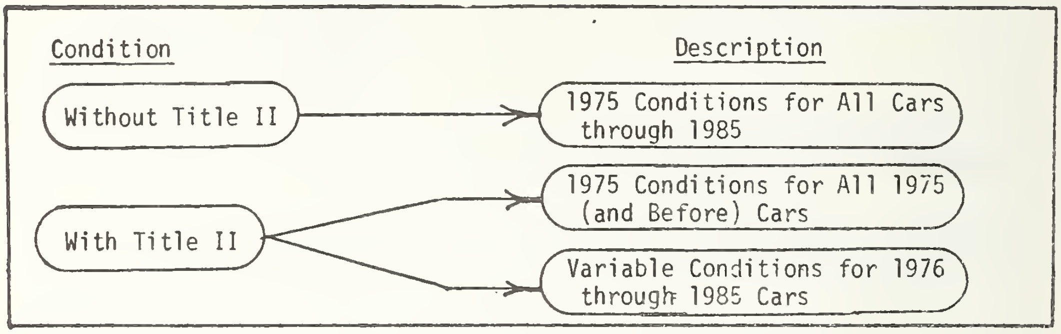

Figure 5-1. Definition of "Without Title II" and "With Title II" conditions.

5.3 Conceptual Outline of the Accident Model

In its simplest outline form, the Accident Model appears as shown in Figure 5-2. Inputs and principal outputs are discussed below. Details of computations are presented in Section 5.4.

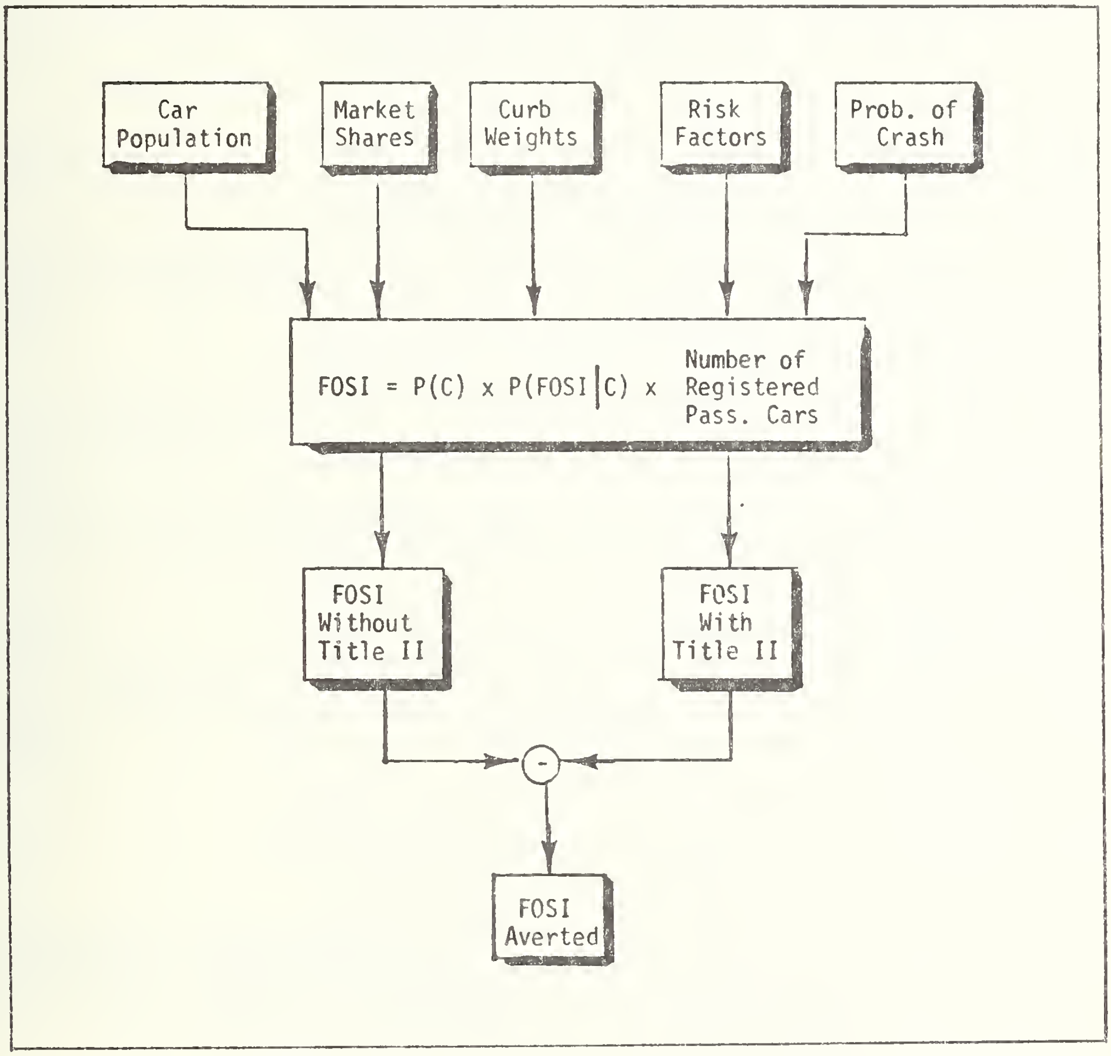

Figure 5-2. The Accident Model.

5.3.1 Inputs

The inputs to the Accident Model are:

- Number of Registered Cars (Car Population)
  - 1975 (and before) through 1985, by Model Year
- Market Shares for 16 Cars (or, 4 car classes)
  - For 1975 and before, indicates how present car population is distributed among the 16 car types
  - For 1976 through 1985, indicates the sales distribution for each model year
- Car Weights for 16 Cars (or, 4 car classes)
  - For 1975 and before, these are curb weights of the 16 cars that typify the present car population
  - For 1976 through 1985, changes in Car Weights are assumed to be correlated with improvements in crashworthiness, damage repairability, etc.
- Risk Factors for 16 Cars (or, 4 car classes)
  - For 1975 and before, these are the conditional probability of FOSI, given that a car is in a crash. Estimates based on empirical data (North Carolina, New York State, etc.) will be used.
  - For 1976 through 1985, projections will be used of improvements in Risk Factors, correlated with improvements in crashworthiness
- Crash Probabilities
  - These can be input for each year (1975 through 1985)
  - In most instances, Crash Probability will be assumed to be constant for all years.

5.3.2 Outputs

The principal outputs from the Accident Model are:

- Fatal or Serious Injuries Without Title II
  - The Model assumes that the Market Shares, Car Weights, and Risk Factors specified for 1975 and Before continue throughout the 1976-1985 period. FOSI are computed for each of the ten years, summed and the 10-year average is determined.
- Fatal or Serious Injuries With Title II
  - The Model uses the Market Shares, Car Weights, and Risk Factors specified for each of the ten years: 1976 through 1985. Thus, the Model can accommodate sudden shifts (possibly due to new laws, restrictions, taxes, etc.) or gradual changes over several years. FOSI are computed for each of the ten years, summed and the 10-year average is determined.
- Fatal or Serious Injuries Averted Due to Availability of Title II Information
  - The Model computes for each year the difference between FOSI for the Without Title II condition and the With Title II condition. These are summed and the 10-year average is determined. These data are also presented as a percentage, relative to the FOSI that would have occurred under the Without Title II condition.

5.4 The Structure of the Accident Model

The basic Accident Model comprises ten steps, as shown in the flow diagram in Figure 5-3.

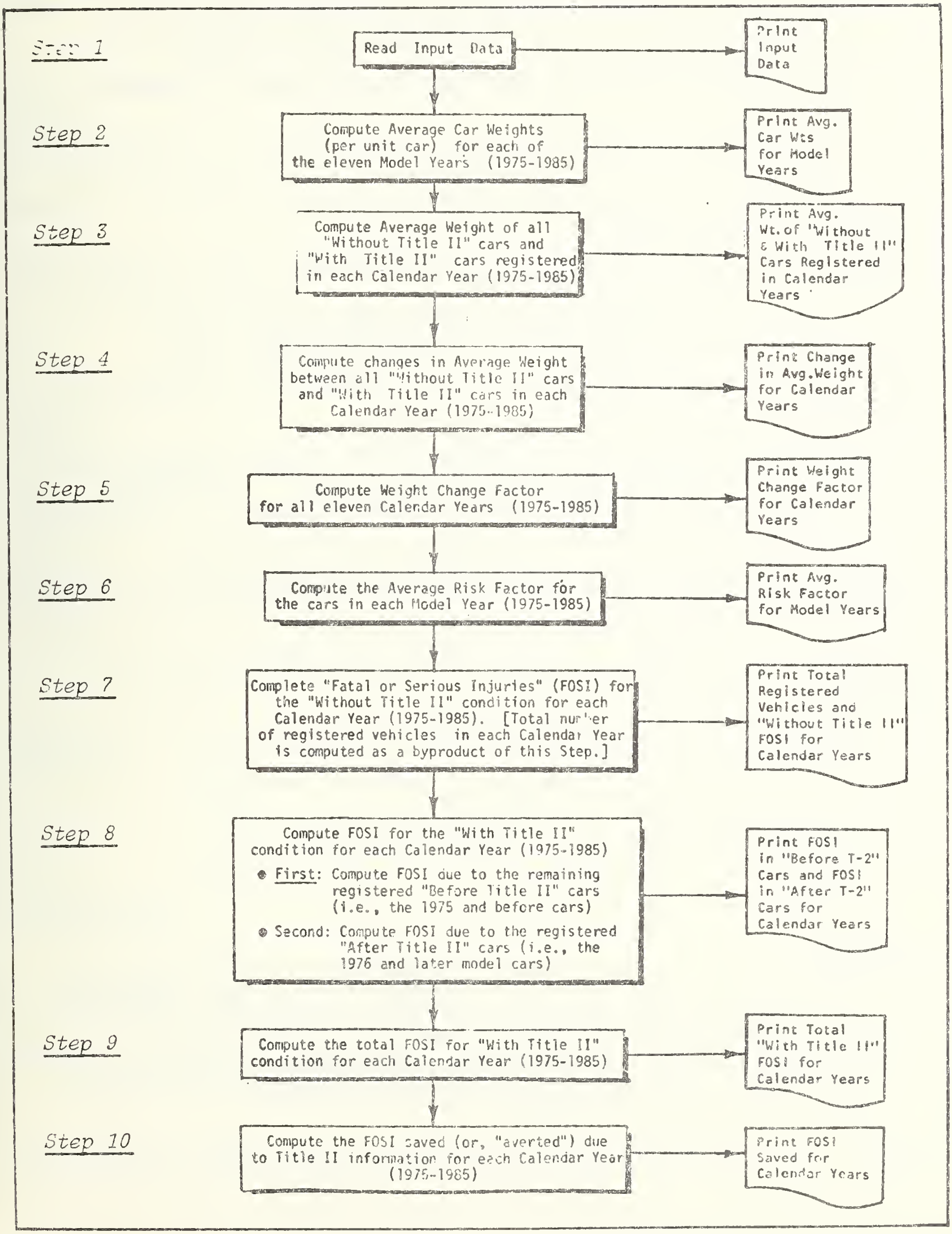

Figure 5-3. Flow diagram for the basic Accident Model.

Each of the ten steps is described below. The format chosen for the descriptions is "pseudo-FORTRAN": a mixture of mathematical notation and computer language. We have found this style to be both terse for general readers and sufficiently descriptive and logically concise for computer programmers.

Step 1

Objective: Read input data.

Inputs:
- No. of Registered Cars (for 1975* - 1985, by Model Year and Calendar Year)
- Market Shares (for 1975-1985, by Model Year)
- Car Weights (for 1975-1985, by Model Year)
- Risk Factors (for 1975-1985, by Model Year)
- Crash Probabilities (for 1975-1985, by Calendar Year)

Computations: None

Outputs: The input data are printed out for completeness and verification of data used.

Step 2

Objective: Compute Average Car Weights (i.e., per unit car) for each of the eleven Model Years (1975-1985).

Inputs: Car Weight and Market Shares (1975-1985 by Model Year)

Computations:

DO ## M = 1, 11

$$\text{YRWT(M)} = \frac{\sum_{N=1}^{16} \text{CARWT(M, N)*SHARE(M, N)}}{\sum_{N+1}^{16} \text{SHARE(M, N)}}$$

Comments:

1. Subscripts "M" and "N" are used here (and in all other Steps) to denote operations over Model Years and the 16 car types, respectively.
2. Normally, the sum of the Market Shares will equal 1. However, the denominator term is included in the above equation to provide normalization, in the event the Market Shares are expressed in some other metric, such as percent.

Output: Average Car Weights per unit car (1975-1985, by Model Year)

*Throughout, all references to "1975" mean "1975 and Before."

Step 3

Objective: Compute Average Weight of all "Without Title II" cars and "With Title II" cars registered in each Calendar Year (1975-1985).

Inputs: Car Population Matrix, Avg. Wt. of Cars in a Model Year.

Computations:

AVG WT (1) = YRWT (1)

DO ## K = 2, 11

$$AVGWT(K) = \frac{\sum_{M=1}^{K} CARS(K, M) * YRWT(M)}{\sum_{M=1}^{K} CARS(K, M)}$$

Comments:

The first term [AVGWT(1)] is the average weight of "Without Title II" cars in <u>any</u> year. The other terms (subscript 2 through 11) are the average weights of all "With Title II" cars in each of the Calendar Years 1976-1985.

Output: Average Weights of "Without Title II" and "With Title II" cars.

Step 4

Objective: Compute the difference (in hundreds of pounds) in Average Weight of "Without Title II' and "With Title II" cars in each Calendar Year (1975-1985).

Input: Average Weights of "Without Title II" and "With Title II" Cars.

Computations:

DO ## K = 1, 11

$$DELWT(K) = \frac{AVGWT(K) - AVGWT(1)}{100}$$

Output: Difference (in 100's of lbs) in Average Weight of all "Without Title II" and "With Title II" cars.

Step 5

Objective: Compute the Weight Change Factor for each Calendar Year (1975-1985).

Input: Difference in Avg. Wt. of "Without Title II" and "With Title II" cars.

Computations:

DO ## K = 1, 11

$$\text{WTFAC(K)} = \left[1 + \frac{\text{DELWT(K)}}{100}\right]$$

Comment:

The derivation of the above expression is given in Appendix H.

Output: Weight Change Factor.

Step 6

Objective: Compute the Average Risk Factor for cars in each Model Year (1975-1985).

Inputs: Risk Factors and Market Shares for Model Years

Computations:

DO ## M = 1, 11

$$\text{ARF(M)} = \frac{\sum_{N=1}^{16} \text{RISK(M, N)*SHARE(M, N)}}{\sum_{N=1}^{16} \text{SHARE(M, N)}}$$

Comments:

Normally, the sum of the Market Shares will equal 1. However, the denominator term is included in the above equation to provide normalization, in the event the Market Shares are expressed in some other metric, such as percent.

Output: Average Risk Factors for each Model Year.

Step 7

Objective: Compute Fatal or Serious Injuries (FOSI) for the "Without Title II" condition for each Calendar Year (1975-1985).

Inputs: Car Population Matrix, Prob. of Crash, and Average Risk Factors

Computations:

DO ## K = 1, 11

$$TOTCAR(K) = \sum_{M=1}^{K} CARS(K, M)$$

FOSIN2(K) = PROBCR(K)*ARF(1)*TOTCAR(K)

Outputs: Total cars registered in each Calendar Year, and FOSI by Calendar Year for the "Without Title II" Condition.

Step 8

Objective: Compute FOSI for the "With Title II" condition for each Calendar Year (1975-1985).

- First, compute the FOSI due to the "Before Title II" cars (i.e., the 1975 and before cars).
- Second, compute the FOSI due to the "After Title II" cars (i.e., the 1976 through 1985 cars).

Inputs: Car Population Matrix, Weight Change Factors, Average Risk Factors, and Probability of Crash.

Computations: For FOSI due to "Before Title II" cars:

DO ## K = 1, 11

FOSI B2(K) = PROBCR(K)*WTFAC(K)*ARF(1)*CARS(K,1)

For FOSI due to "After Title II" cars:

FOSIA2(1) = 0.0

DO ## K = 2, 11

$$FOSIA2(K) = PROBCR(K)*WTFAC(K)*\sum_{M=2}^{K} ARF(M)*CARS(K, M)$$

Outputs: FOSI due to "Before Title II Cars" and "After Title II" Cars in each Calendar Year.

Step 9

Objective: Compute the total FOSI for the "With Title II" condition for each Calendar Year (1975-1980).

Inputs: FOSI for "Before Title II," and FOSI for "After Title II."

Computations:

```
DO ## K = 1, 11
FOSIW2(K) = FOSIB2(K) + FOSIA2(K)
```

Output: Total FOSI for the "With Title II" condition.

Step 10

Objective: Compute the FOSI saved (or, averted) due to the availability of TItle II information, for each Calendar Year (1975-1980).

Inputs: FOSI for the "Without Title II" condition, and FOSI for the "With Title II" condition.

Computations:

```
DO ## K = 1, 11
FOSISD(V) = FOSIN2(K) - FOSIW2(K)
```

Output: FOSI saved due to availability of Title II information

5.5 Characteristics of the Accident Model

The basic outputs of the Accident Model are Fatal or Serious Injuries (FOSI) under Without Title II and With Title II conditions, for the ten-year period 1976-1985. For this study we are primarily interested in the difference in FOSI between these two conditions. A typical example of the time response of these variables is shown in Figure 5-4. The figure illustrates that under the Without Title II condition the FOSI would grow with the projected growth of the passenger car population from about 95 million in 1975 to 138 million in 1985. In the "scenario" which produced the results shown in Figure 5-4, it is assumed that the buyers have significantly shifted to the purchase of small cars: the results are for a 20 percent Market Share Shift Down to small cars as indicated in Table 5-1.

TABLE 5-1

MARKET SHARE SHIFT FOR THE EXAMPLE IN FIGURE 5-4

Car Class	Market Shares (%)	
	1975 & Before	1976 & Later
Subcompact	20	25
Compact	20	25
Intermediate	40	35
Full Size	20	15

For the results shown in Figure 5-4, we have assumed that the probability that a passenger car will be in a crash is 0.10 each year. However, it is pointed out that this value, based on 1974 New York State data, is actually immaterial to the information of greatest interest: the percent of FOSI averted, due to the availability of Title II information, is completely independent of the (non-zero) magnitude of this term.

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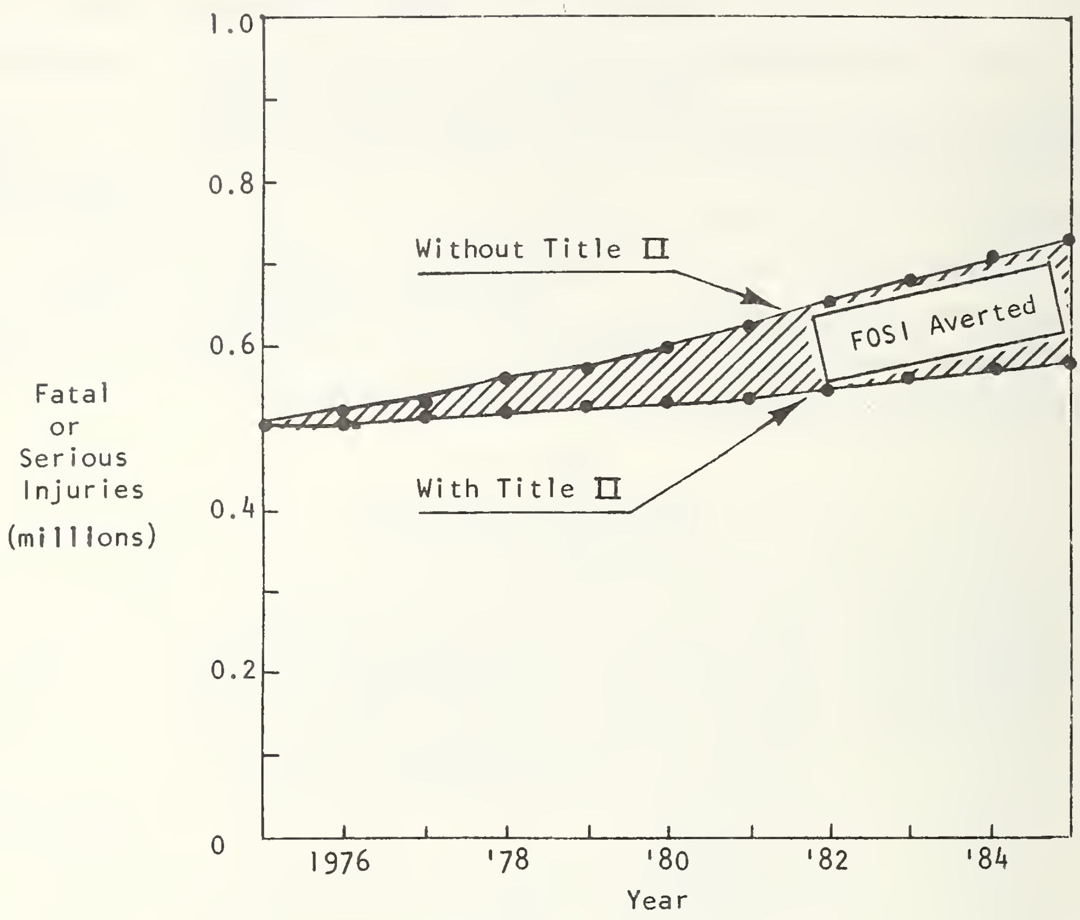
*Market Share Shift is defined as the sum of the percent of the total market lost by one or more sectors, the percent gained by one or more of the remaining sectors. In the example shown in Table 5-4, a "uniform" Market Share Shift has taken place, because 10 percent has been lost by the larger cars, in equal shares, and 10 percent has been gained by the smaller cars in equal shares.



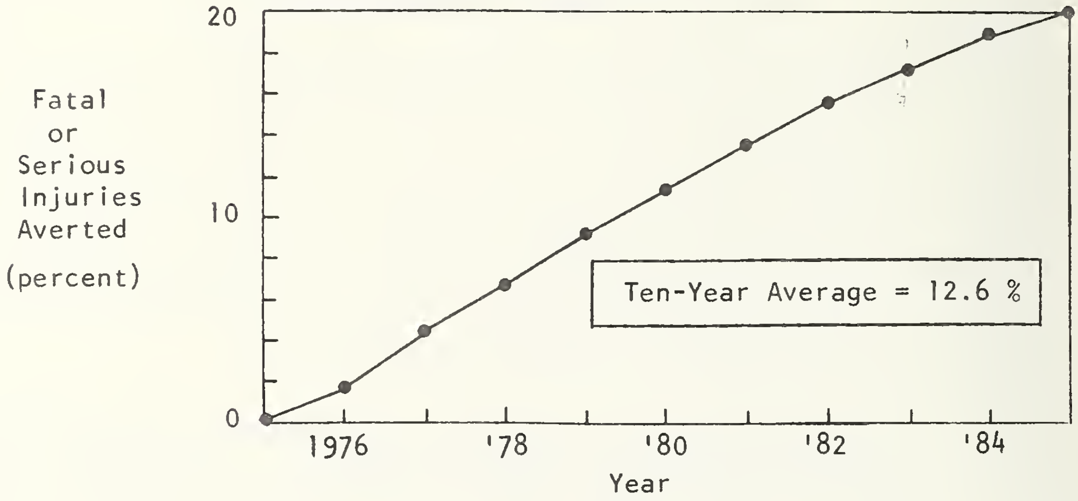


Figure 5-4. Example of Accident Model results.

It is noted that the projected car population used in this example has been a constant condition throughout most of this study. The projections include attrition of older cars, so by 1985, only 13 percent of the registered passenger cars are "Before Title II" (i.e., produced in 1975 or before). The car population matrix used in the Accident Model assumes that model year attrition takes place over 17 years. However, only half the cars produced in a model year are registered ten years later, according to the matrix.

In addition to the Market Share Shift conditions, Figure 5-4 reflects an incremental reduction of 0.015 in all Risk Factors (i.e., the conditional probabilities that at least one FOSI will occur, given that a car is in a crash) and an increase in Weight of 100 lb for all cars. The weight increase is assumed to be commensurate with the decrease in Risk Factor.

In general, shifting to small cars tends to increase the FOSI incurred because smaller cars are not as safe as larger cars. Also, increase in weight increases the FOSI incurred, because the heavier cars are more "aggressive," relative to smaller cars. Reduction in Risk Factor increases the FOSI averted. The Accident Model is most sensitive to (percentage) changes in Risk Factor, as will be discussed below. Because of this high sensitivity, the net result of the parametric changes under the With Title II condition is a substantial number of FOSI averted over the ten-year period.

In this example, it has been assumed that all changes take place in 1976 and continue unchanged throughout 1976-1985. During that time the projected passenger car population increases by about 43 million cars. The percentage of FOSI averted displays an almost linearly increasing trend, primarily because new cars have been assumed to have been built to be substantially safer, to get better Title II ratings for crashworthiness. For most rational conceptions of the next ten years, the trends shown in Figure 5-4 are fairly typical (although in some instances the FOSI averted may be negative, of course). Therefore, it was decided to use the ten-year average of percent FOSI averted as a single number index by which to compare the effect of various parametric changes in input data for the Accident Model. *The reader should keep in mind that in almost all instances discussed in this report, the ten-year average of FOSI averted is based on the area under a curve which approximates a right triangle. Therefore, the ten-year average value is approximately one-half the number of FOSI averted in the tenth year (1985).*

5.6 Sensitivity of the Accident Model

A computer model is a logical framework for number manipulation. Usually, in a model which is meant to simulate approximately an essentially real-world situation, the parameters (or, variables) are exercised over relatively narrow ranges. The response of the model indicates its sensitivity to changes in the parameters. A model may be very sensitive to some parameters, and relatively insensitive to other parameters. The determination of such model characteristics is commonly known as sensitivity analysis.

There are at least seven important variables in this Accident Model, each of which has an impact on the primary output variable: the ten-year average value of FOSI averted. Therefore, an extensive sensitivity analysis effort was conducted to characterize the response of the Accident Model to changes in input values.

Sensitivity analyses were conducted based on variation, singly or in combination, of the following parameters.

- Market Share Shifts for 1976 and Later Cars and Car Classes
- Initial Shares for 1975 and Before Car Classes
- Weights of Car Classes
- Risk Factors for Car Classes
- Volume of New Car Sales

A total of 15 "scenarios" was investigated; the basic characteristics of the scenarios are listed in Table 5-2. The results of the sensitivity analyses are briefly summarized below.

- *Market Share Shifts for 1976 and Later Cars and Car Classes*

  Under all conditions investigated, it was found that Fatal or Serious Injuries were averted when the Market Share Shift was from smaller to larger cars. Conversely, if the shift was to small cars, the more FOSI were incurred. An approximate rule-of-thumb characterizing the Accident Model is

$$\begin{array}{c}\text{\% FOSI}\\ \text{Averted}\\ \text{(10-yr. Avg.)}\end{array} = \pm \left(0.09 \text{ to } 0.12\right) \times \left[\begin{array}{ll}\text{\% Market} & \text{Share}\\ \text{Shift Up} & (+)\\ \text{or Down} & (-)\end{array}\right]$$

  That is, to a first approximation a 10 percent Market Share Shift to large cars will result in about 1 percent FOSI being averted, relative to the assumed condition that buyers would continue to purchase passenger cars in proportion to the 1975 and Before car population.

- *Market Shares for "1975 and Before" Car Classes*

  We were concerned about possible impacts of errors in our assumption of the relative proportions of presently registered cars (1975 and Before) in the four car classes used

TABLE 5-2

CHARACTERISTICS OF ACCIDENT MODEL SCENARIOS

Scenario	Description	Market Share Shift		Initial Market Shares				Type of Market Share Shift		Weight Change		Risk Change		New Car Sales	
		Up	Down	SC	C	I	FS	Abrupt	Gradual	Increase	Decrease	Increase	Decrease	"Normal"	90%
1	Burke; Shift to Large Cars	✓		.26	.24	.27	.23	✓		--	--	--	--	✓	
2	U.S. Testing; Shift to Large Cars	✓		.21	.27	.24	.28	✓		--	--	--	--	✓	
3	1974 Shares; Shift to Large Cars	✓		.22	.25	.30	.23	✓		--	--	--	--	✓	
Wuerde-mann	Shift to Larger, Heavier, Safer Cars	✓		.20	.25	.30	.25	✓	1976-1980	✓			✓	✓	
4	Shift to Small Cars		✓	.20	.20	.40	.20	✓		--	--	--	--	✓	
5	Shift to Larger, Lighter, Riskier Cars	✓		.20	.20	.40	.20	✓			✓	✓		✓	
6	Shift to Smaller, Heavier, Safer Cars		✓	.20	.20	.40	.20	✓		✓			✓	✓	
7	Repeat Scenarios #4 & #6 with Wuerdemann Initial M.S.		✓	.20	.25	.30	.25	✓		✓			✓	✓	
8	Repeat Scenario #7 with Erdmann Initial Market Shares		✓	.20	.20	.20	.40	✓		✓			✓	✓	
9	Repeat Scenario #8 with Different Final Market Shares		✓	.20	.20	.20	.40	✓		✓			✓	✓	
10	Repeat Scenarios #4 & #6 with 4-Year Market Share Shift		✓	.20	.20	.40	.20		1976-1979		✓		✓	✓	
11	Repeat Scenarios #4 & #6 with 50% Market Share Shift		✓	.20	.20	.40	.20	✓		✓			✓	✓	
12	Repeat Scenario #10 with 90% New Car Sales		✓	.20	.20	.40	.20	✓	1976-1979		✓		✓		✓
13	Shift to Small Cars, then Back to Large Cars	✓	✓ (Net)	.20	.20	.40	.20		1976-1979		✓	✓	✓	✓	
14	Air Bags		✓	.20	.20	.40	.20				✓			✓	✓

in this study. We therefore considered three different sets of initial Market Shares, and considered the change in the most sensitive ratio in this model, which is % FOSI/% Incremental Decrease in Risk Factor. It was found that this ratio varied by no more than about ± 2 percent, even for significant changes in the assumed Initial Market Shares. It was therefore concluded:

> *In terms of 10-year averages of percent FOSI averted, the results from this Accident Model are relatively insensitive to the accuracy of the Initial Market Shares used for the existing registered car population (1975 and Before).*

- *Weights of Car Classes*

  Increasing the weight of cars makes heavier, larger ones more "aggressive" than lighter, smaller ones. In the Accident Model, the Risk Factors are modified each year, as the average weight of the entire car population increases or decreases (see Steps 4, 5, and 8 in the description of the Accident Model above). Average weights of car classes were varied by fixed amounts (100 lb and 200 lb) and by percent (10% and 20%) from which the approximate factors (or, rules-of-thumb) were derived:

$$\begin{matrix}\text{\% FOSI} \\ \text{Averted} \\ \text{(10-yr. Avg.)}\end{matrix} = \pm \left(0.49 \text{ to } 0.35\right) \times \left[\begin{matrix}\text{Weight Decrease (+)} \\ \text{or Increase (-) in} \\ \text{100 bl}\end{matrix}\right]$$

  or

$$\begin{matrix}\text{\% FOSI} \\ \text{Averted} \\ \text{(10-yr. Avg.)}\end{matrix} = \pm \left(0.19\right) \times \left[\begin{matrix}\text{\% Weight Decrease (+)} \\ \text{or Increase (-)}\end{matrix}\right]$$

  The incremental or percentage weight changes apply to nominal average weights for the four car classes:

Subcompact	Compact	Intermediate	Full Size
2200 lb	3200 lb	3800 lb	4400 lb

  These average weights were used as the basic weights for the 1975 and Before cars (and the Without Title II conditions) in all but the first three Accident Model scenarios.

- *Risk Factors for Car Classes*

  As was the case with weights, a basic set of Risk Factors was used for the 1975 and Before cars (and the Without Title II Condition). They are:

Subcompact	Compact	Intermediate	Full Size
0.075	0.065	0.045	0.035

  Reductions in Risk Factors were made both incrementally and as a percentage of the initial value. Incremental changes involved reductions of 0.015 (or, an incremental change of -1.5%) and 0.03 (or, an incremental change of -3.0%). There was an exception to these statements; for Full Size cars, an incremental change of -2.5% was made, because it was assumed that the conditional probability of a FOSI occurring, given that a car is in a crash, would probably not drop below 1.0%, regardless of what conventionally plausible steps are taken to improve crashworthiness. In addition to the incremental changes described,

Risk Factors were also reduced by 10% and 20%. (That is, a 10% reduction in a Risk Factor of 0.065 would result in a new value of 0.0585.)

Under the stated conditions, it was found that Risk Factor is the most sensitive parameter in the Accident Model, giving rise to the following rules-of-thumb:

$$\begin{array}{c}\text{\% FOSI}\\ \text{Averted}\\ \text{(10-yr. Avg.)}\end{array} = \pm \left(10.2 \text{ to } 9.72\right) \times \left[\begin{array}{l}\text{\% Incremental}\\ \text{Increase (+) or}\\ \text{Decrease (-) in}\\ \text{Risk Factor}\end{array}\right]$$

or

$$\begin{array}{c}\text{\% FOSI}\\ \text{Averted}\\ \text{(10-yr. Avg.)}\end{array} = \pm \left(0.54 \text{ to } 0.50\right) \times \left[\begin{array}{l}\text{\% Increase (+)}\\ \text{or Decrease (-)}\\ \text{in Risk Factor}\end{array}\right]$$

- *Volume of New Car Sales*

The car population model used in this study is based on passenger car registration data developed by Joksch* and projections of future car sales prepared by the Department of Commerce. † As noted previously, the projection indicates that registrations will increase from about 95 million passenger cars in 1975 to approximately 138 million in 1985--an increase of 43 million cars. This is based on annual sales increasing from about 10.6 million for the 1976 model year to about 15.5 million for the 1985 model year.

The present economic and energy climate suggests that annual sales might not achieve such volumes. Therefore, a sensitivity analysis was conducted to determine the impact of a uniform 10 percent reduction in new car sales in the 10-year period 1976-1985. This reduction in new car sales results in a reduction in the magnitude of FOSI averted of about 5 percent, giving an approximate rule-of-thumb:

$$\begin{array}{c}\text{Reduction in}\\ \text{\% FOSI}\\ \text{Averted}\\ \text{(10-yr. Avg.)}\end{array} = \left(0.045 \text{ to } 0.05\right) \times \left[\begin{array}{c}\text{\% Reduction}\\ \text{in New Car}\\ \text{Sales}\end{array}\right]$$

***An Accident Trend Model*, The Center for the Environment and Man, Inc., Report DOT-HS-246-3-670, August 1974.

†U.S. Department of Commerce, *U.S. Industrial Outlook, 1975, with Projections to 1980*, August 1974.

5.7 Selected Examples of Accident Model Results

To provide the reader with more insight into the general response characteristics of the Accident Model, graphical results are presented and discussed for six sensitivity analyses which used data from nine of the 15 scenarios.

Scenarios #4, #6, and #11

Purpose: To determine the impact of:

- Market Share Shifts up to large cars and down to small cars.
- Increase in the weight of cars commensurate with decreases in Risk Factor.
- Decreases in Risk Factor, due to manufacturing improvements as a consequence of Title II information.

Results: The data from the scenarios are shown graphically in Figure 5-5. Note that results due to Market Share Shifts are approximately linear on either side of the origin. However, the slope of the FOSI averted response is slightly greater for Market Share Shifts up to large cars, relative to Market Share Shifts down to small cars.

Decreasing risk (improving crashworthiness) dramatically improves FOSI averted.

Increasing weight, assumed here to be needed to improve crashworthiness, makes new cars more "aggressive," relative to the 1975 and Before cars, and decreases FOSI averted as illustrated by Figure 5-5.

The effects of varying the above parameters are independent, to a first approximation. Therefore, a linear approximation to the Accident Model would be:

$$\begin{array}{c}\text{\% FOSI}\\ \text{Averted}\\ \text{(10-yr. Avg.)}\end{array} \cong 10 \times \begin{bmatrix}\text{\% Incremental}\\ \text{Decrease in}\\ \text{Risk Factor}\end{bmatrix} \pm 0.1 \begin{bmatrix}\text{\% Market Share}\\ \text{Shift Up (+)}\\ \text{or Down (-)}\end{bmatrix} - 0.4 \times \begin{bmatrix}\text{Increase in}\\ \text{Car Weight}\\ \text{in 100 lb}\end{bmatrix}$$

Summary: This sensitivity analysis shows that this Accident Model has the following characteristics:

- The Accident Model output (10-year average of % FOSI Averted) is very sensitive to improvements in Risk Factor.
- A shift to large cars, which could be a consequence of Title II crashworthiness information, will result in a reduction in fatal or serious injuries.

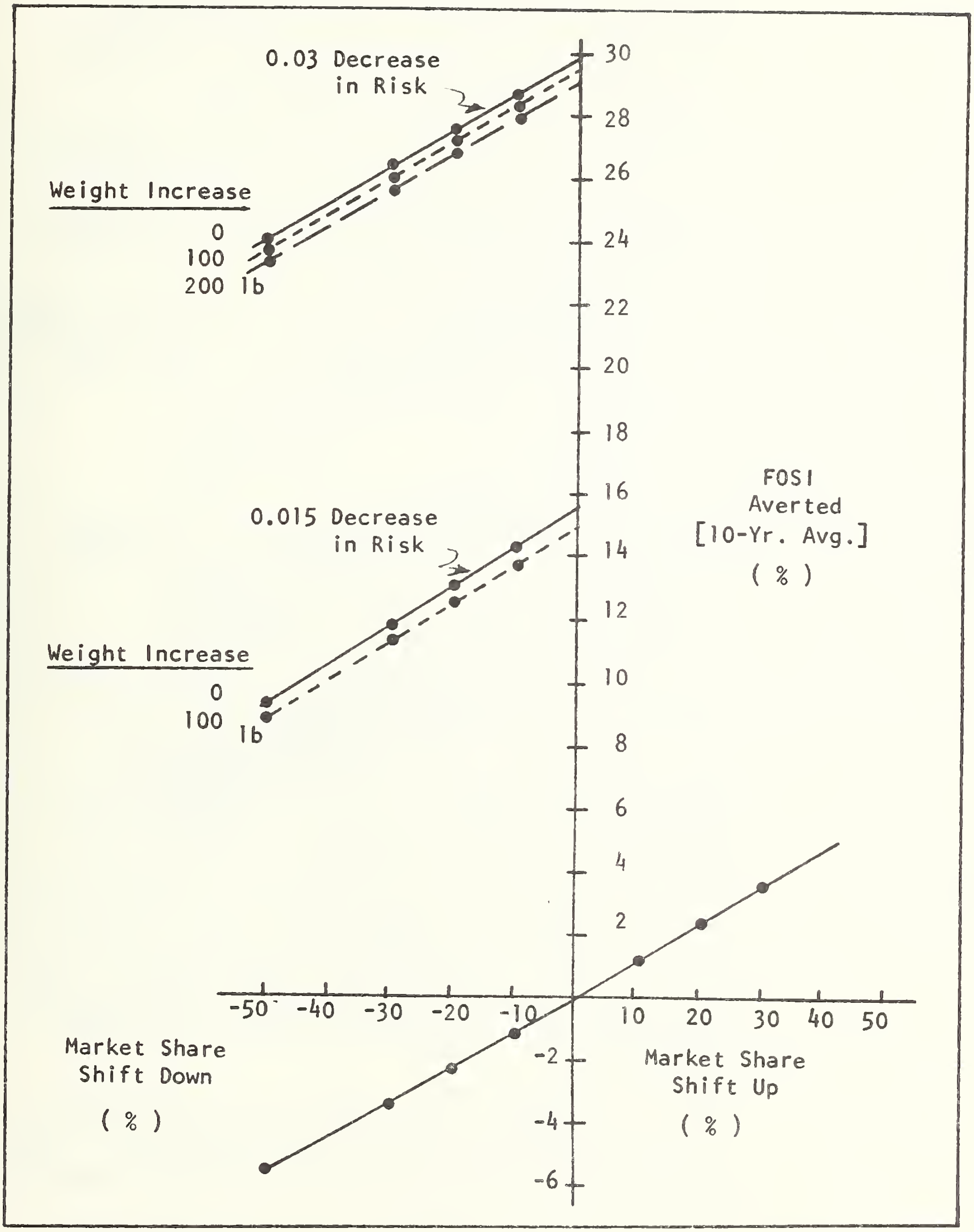


Figure 5-5. Results for Accident Model Scenarios #4, #6, and #11.

- A shift to small cars, which could be a consequence of increased gasoline cost and/or a shortage of gasoline or a tax on larger cars, will result in an increase in fatal or serious injuries, relative to the continuation of present passenger car registration conditions.
- Small Market Share Shifts (i.e., a few percent) have relatively little impact on fatal or serious injuries. Other factors, such as reduction of speed limits or small improvements in crashworthiness, may overwhelm the minor impact of a Market Share Shift of 10 percent or less.
- Increasing the weight of present cars to make them more crashworthy would have a small, but noticeable, effect, reducing somewhat the total fatal or serious injuries averted.

Scenario #5

Purpose: To determine the impact of:

- Market Share Shift up to large cars as a consequence of Title II crashworthiness information.
- Weight reduction to improve gas economy.
- Risk increase due to reduced weight.

Results: The data are shown graphically in Figure 5-6. Note that both reduced weight and Market Share Shifts up to larger cars increase FOSI averted. However, if the weight of all cars is reduced to improve engine efficiency (more miles/gal), and if this results in an increase in Risk Factor (by possible 10% or 20%), then the overall net effect may be to increase fatal or serious injuries. This occurs primarily because the older cars (1975 and Before) are heavier and appear more aggressive than the newer, lighter, and less crashworthy cars. (It should be kept in mind that our car population model indicates that nearly 18 million 1975 and Before cars will still be registered in 1985, and more than half of them will be registered in 1981.)

Figure 5-6 suggests that variations in Weight, Risk Factor, and Market Share Shift are both linear and, to a first approximation, essentially independent. Therefore, a linear approximation to the Accident Model would be:

$$\begin{array}{c}\text{\% FOSI}\\ \text{Averted}\\ \text{(10-yr. Avg.)}\end{array} \cong \frac{1}{9} \times \begin{bmatrix}\text{\% Market Share}\\ \text{Shift Up}\end{bmatrix} - \frac{1}{5} \times \begin{bmatrix}\text{\% Reduction}\\ \text{in Weight}\end{bmatrix} - \frac{1}{2} \begin{bmatrix}\text{\% Increase}\\ \text{in Risk Factor}\end{bmatrix}$$

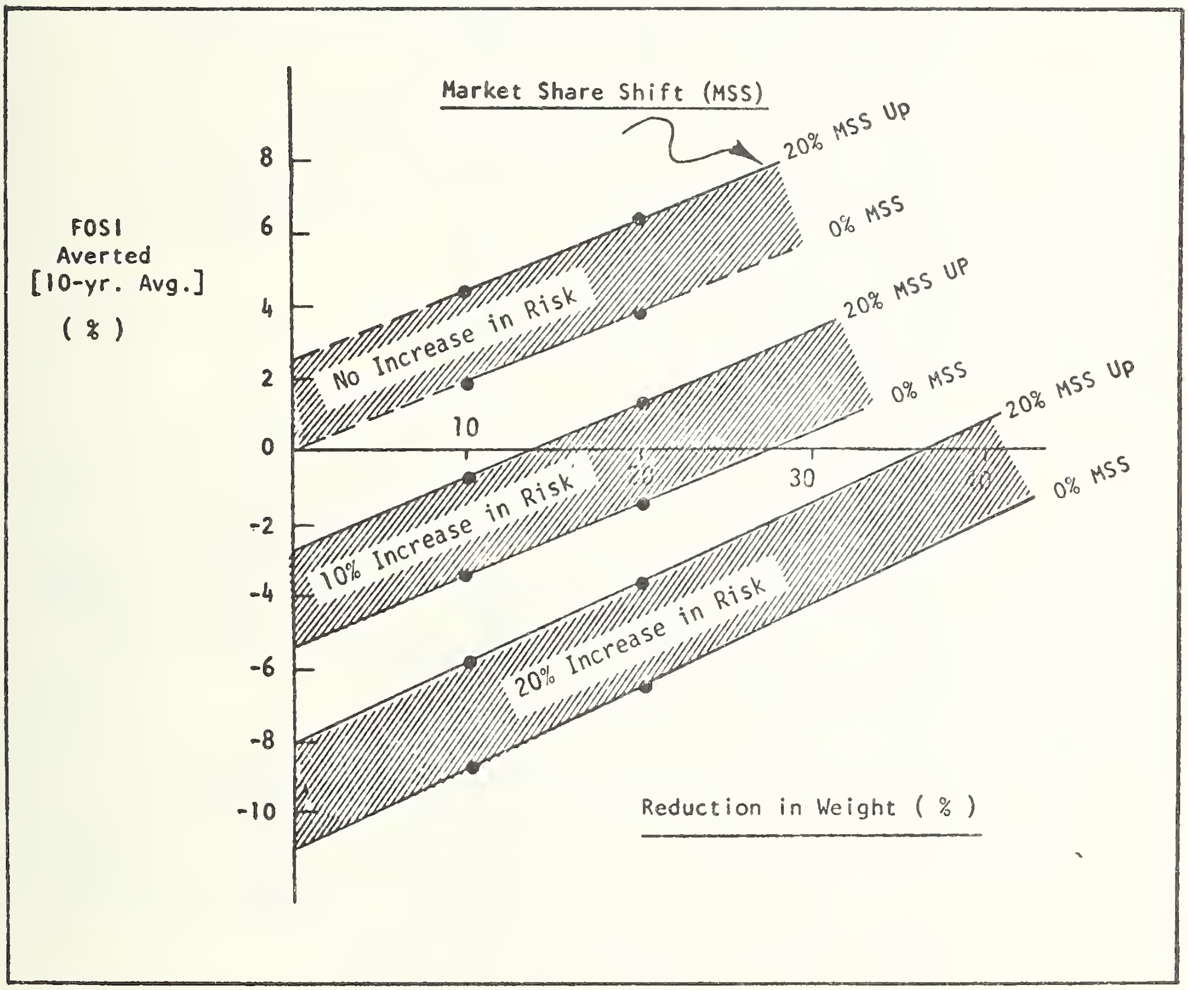


Figure 5-6. Results for Accident Model Scenario #5.

It should be noted that this approximate relationship differs from the one given for Scenarios #4, #6, and #11, because here the changes made were percentage changes in the 1975 and Before values, rather than incremental changes. In both cases discussed thus far, the weight and risk changes were applied uniformly to all four classes of car. The Market Share Shifts all involved taking equal fractions of the total market from full size and intermediate cars and giving that in equal amounts to compact and subcompacts (or vice-versa for a shift up to large cars). Also, in both cases, all changes took place in 1976 and continued throughout the 10-year period (i.e., a step-function change).

Scenarios #4 & #6, #7, #8

Purpose: To determine the effect of changes in the Market Shares for 1975 and Before cars.

The Market Shares for 1975 and Before cars are shown graphically in Figure 5-7. The "20%/20%/40%/20%" initial Market Shares were derived from the work by Joksch for the *Accident Trend Model.** The "20%/25%/30%/25%" initial Market Shares were used as a rational variation of the first case, representing a 20% Market Share change. The "20%/20%/20%/40%" initial Market Shares were considered to be an extreme situation, with a 40% shift in initial Market Shares.

Results: Scenarios #7, and #8 were each duplicates of the combined events investigated in Scenarios #4 and #6, except that initial Market Shares were changed, as shown in Figure 5-7. These average values of % FOSI Averted/% Incremental Decrease in Risk Factor are given in Table 5-3. It can be seen that the changes in initial Market Shares have relatively little (within ± 2%) impact on this highly sensitive factor.

Summary: In terms of 10-year averages of percent FOSI averted, the results from this Accident Model are relatively insensitive to the accuracy of the Initial Market Shares used for the existing registered car population (1975 and Before).

**An Accident Trend Model,* The Center for the Environment and Man, Inc., Report DOT-HS-246-3-670, August 1974.

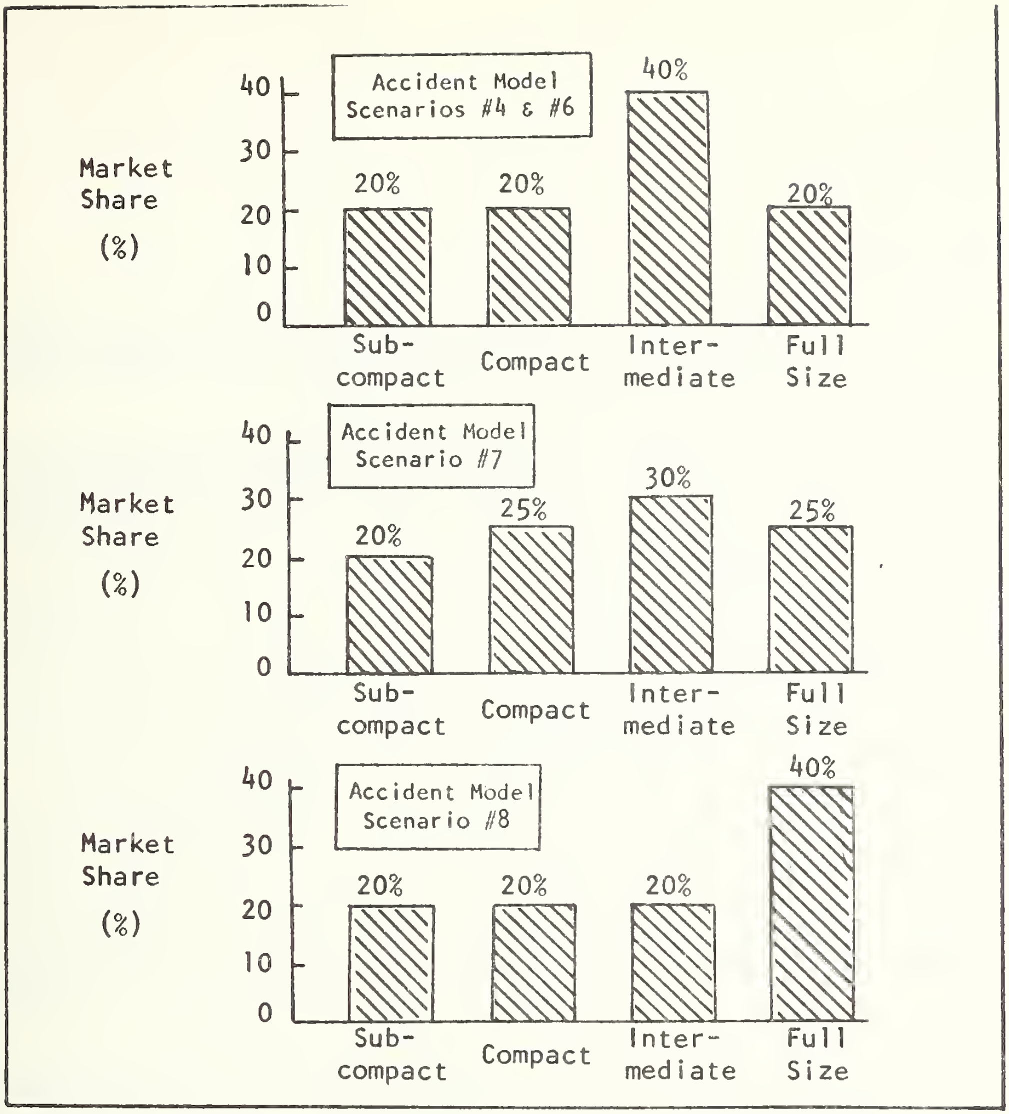


Figure 5-7. Comparison of "1975 & Before" initial market shares.

TABLE 5-3

EFFECT OF CHANGES IN INITIAL MARKET SHARES

Accident Model Scenario	Initial Market Shares				% FOSI Averted / % Incremental Decrease in Risk Factor	Change, Relative to Scenarios #4 & #6 (%)
	Sub-Compact	Compact	Inter-mediate	Full Size		
#4, #6	0.2	0.2	0.4	0.2	9.71	
#7	0.2	0.25	0.3	0.2	9.57	- 1.44
#8	0.2	0.2	0.2	0.4	9.91	+ 2.06

Scenario #10

Purpose: To determine the impact of:

- Market Share Shifts to small cars that take place gradually (and uniformly) over a four-year interval: 1976-1979.
- A decrease in Risk Factor of 0.015, which also takes place uniformly over the four-year period.
- A decrease in Weight of 200 lb average, which takes place uniformly over the same four-year period.

The above conditions were considered to be commensurate with (1) a shift to small cars because of a gasoline shortage; (2) a redirection in weight to further improve gasoline economy; (3) a decrease in risk as a result of manufacturing changes undertaken because of the availability of Title II crashworthiness information; and (4) the expectation that the impact of such changes would likely occur over a period of about four years.

Results: The data from this scenario are plotted in Figure 5-8, along with data for essentially similar conditions taken from Scenarios #4 and #6, where the changes took place abruptly in 1976, rather than gradually over four years.

The impact of gradual change in the parameters over a four-year period is seen to reduce the FOSI averted, but only by about 13% to 23%, depending on conditions investigated.

Summary: As would be expected, when changes take place gradually over several (four) years, rather than abruptly at the beginning of the 10-year period under consideration, the FOSI averted are less in magnitude. For the conditions investigated, the reduction in FOSI averted was in the range of about 13% to 23%.

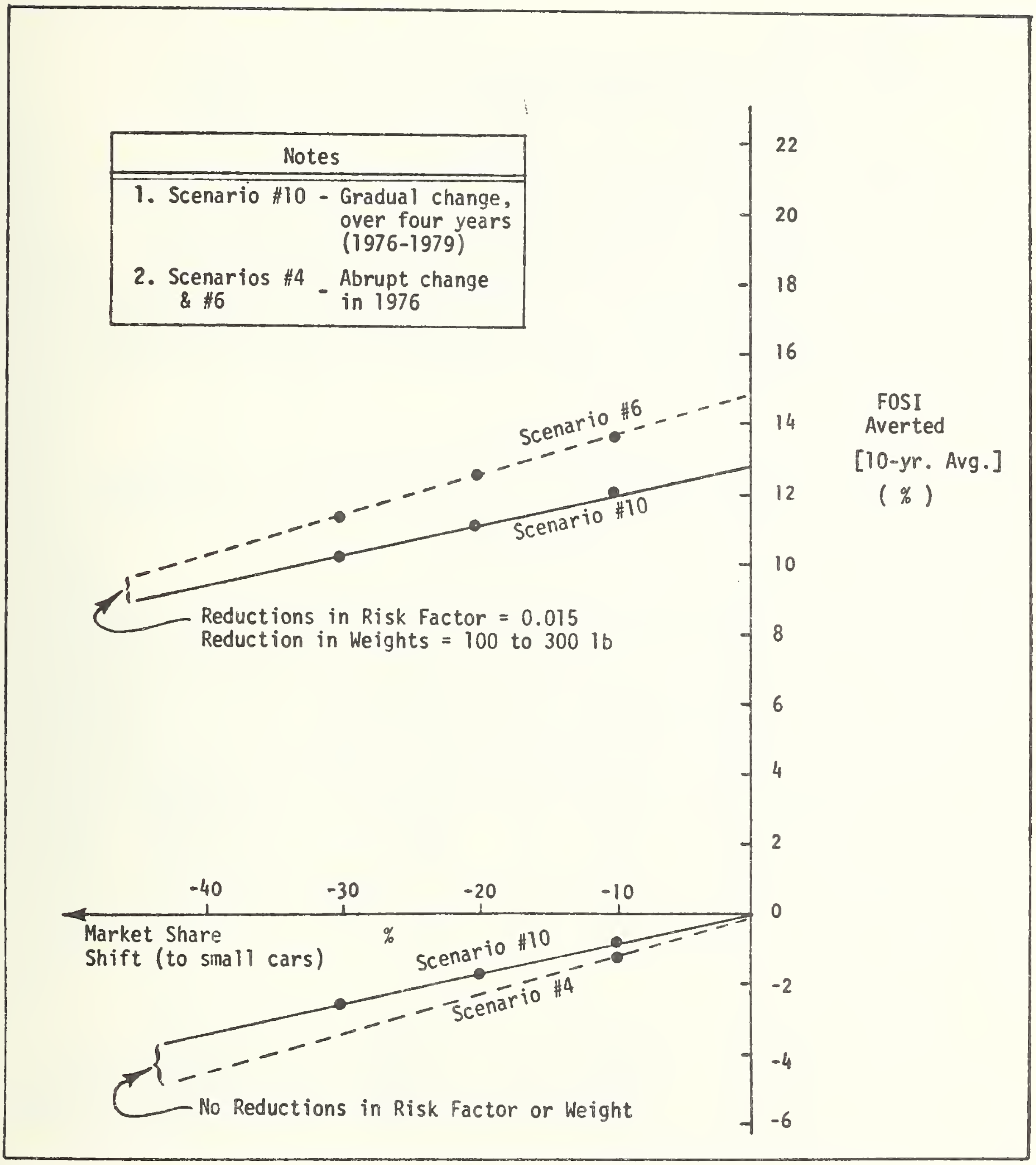


Figure 5-8. Results from Accident Model Scenarios #4, #6, and #10.

Scenario #12

Purpose: To determine the impact of a 10 percent reduction in new car sales, uniformly applied throughout 1976-1985.

Results: The conditions of Accident Model Scenario #10 (described immediately above) were re-run with a 10% reduction in the sale of new cars in each year. The results of this sensitivity analysis are given in Table 5-4. As can be seen in the last line of the table, the reductions in % FOSI averted are of the order of 4.5 to 5.2 percent. (This range of values was further confirmed by a similar analysis conducted as part of Scenario #14.)

TABLE 5-4

IMPACT ON FOSI AVERTED BY A 10% REDUCTION IN NEW CAR SALES; COMPARISON OF DATA FROM ACCIDENT MODEL SCENARIOS #10 AND #12

Scenario	FOSI Averted for Runs							
	10-1 12-1	10-2 12-2	10-3 12-3	10-4 12-4	10-5 12-5	10-6 12-6	10-7 12-7	10-8 12-8
#10	-0.89	-1.80	-2.67	-2.91	12.06	11.10	10.16	9.90
#12	-0.85	-1.71	-2.56	-2.76	11.48	10.57	9.67	9.43
Difference	-0.04	-0.09	-0.13	-0.15	0.58	0.53	0.49	0.47
% of Scenario #10	-4.5	-5.0	-4.8	-5.2	4.81	4.78	4.82	4.75

Summary: Reducing new car sales reduced the number of registered passenger cars and, hence, the number of fatal and serious injuries. The reduction in % FOSI averted (10-year average) is about one-half percent for each one percent reduction in new car sales.

Scenario #14

Purpose: To determine the impact of:

- Incremental reductions in Risk Factor, assumed to be due to the phased implementation of air bags for occupant restraint in an accident, which may occur as a consequence of the availability of Title II crashworthiness information.
- Market Share Shift to small cars because of the high cost and/or availability of gasoline.
- Significant reductions in weight to further improve the miles/gallon performance of passenger cars.
- A gradual introduction of all the above changes, applying them uniformly over the four-year period 1976-1985.

The above conditions were applied in a proportional manner to each of the four car classes, as shown in Table 5-5.

TABLE 5-5

CONDITIONS FOR ACCIDENT MODEL SCENARIO #14

Car Class	Risk Factor		
	Before Title II (1975 & Before)	After Air Bags (1979 & Later)	*Reduction*
Subcompact	0.075	0.045	*0.03*
Compact	0.065	0.035	*0.03*
Intermediate	0.045	0.020	*0.025*
Full Size	0.035	0.015	*0.02*

Car Class	Weight		
Subcompact	2200 lb	2000 lb	*200 lb*
Compact	3200	2900	*300*
Intermediate	3800	3400	*400*
Full Size	4400	3900	*500*

Results: The data from Scenario #14 is shown graphically in Figure 5-9. It is apparent that the changes in Risk Factor, assumed possible through the installation of air bag restraints (plus the use of belts), could create a substantial improvement in % FOSI averted over the 10-year period: about 18 to 22% depending on the Market Share Shift to small cars and the reduction in Weight.

It is also worth noting the linear character of the reduction in FOSI averted caused by going to an extreme Market Share Shift down to small cars of 70%.

It should be held in mind that a 10-year average value of 20% FOSI averted means that in the 10th year (1985) there will be about 40% fewer FOSI than would be the case if the passenger car population continued to grow in proportion to present Market Shares, Weights, and Risk Factors.

(In addition to the results cited, the conditions of the scenario were repeated with a 10% reduction in new car sales. The results confirmed the findings given for Accident Model Scenario #12; that is, a one percent reduction in new car sales reduced the % FOSI averted by about one-half percent, because there are fewer registered cars.)

Summary: Introduction of air bag restraint systems by manufacturers, to show better crashworthiness values in Title II information provided to car buyers, could produce a significant reduction in fatal and serious injuries over the next ten years, even if the bags are phased in over four years, and even if the manufacturers reduce the weight of cars and the buying public shifts signficantly to smaller cars.

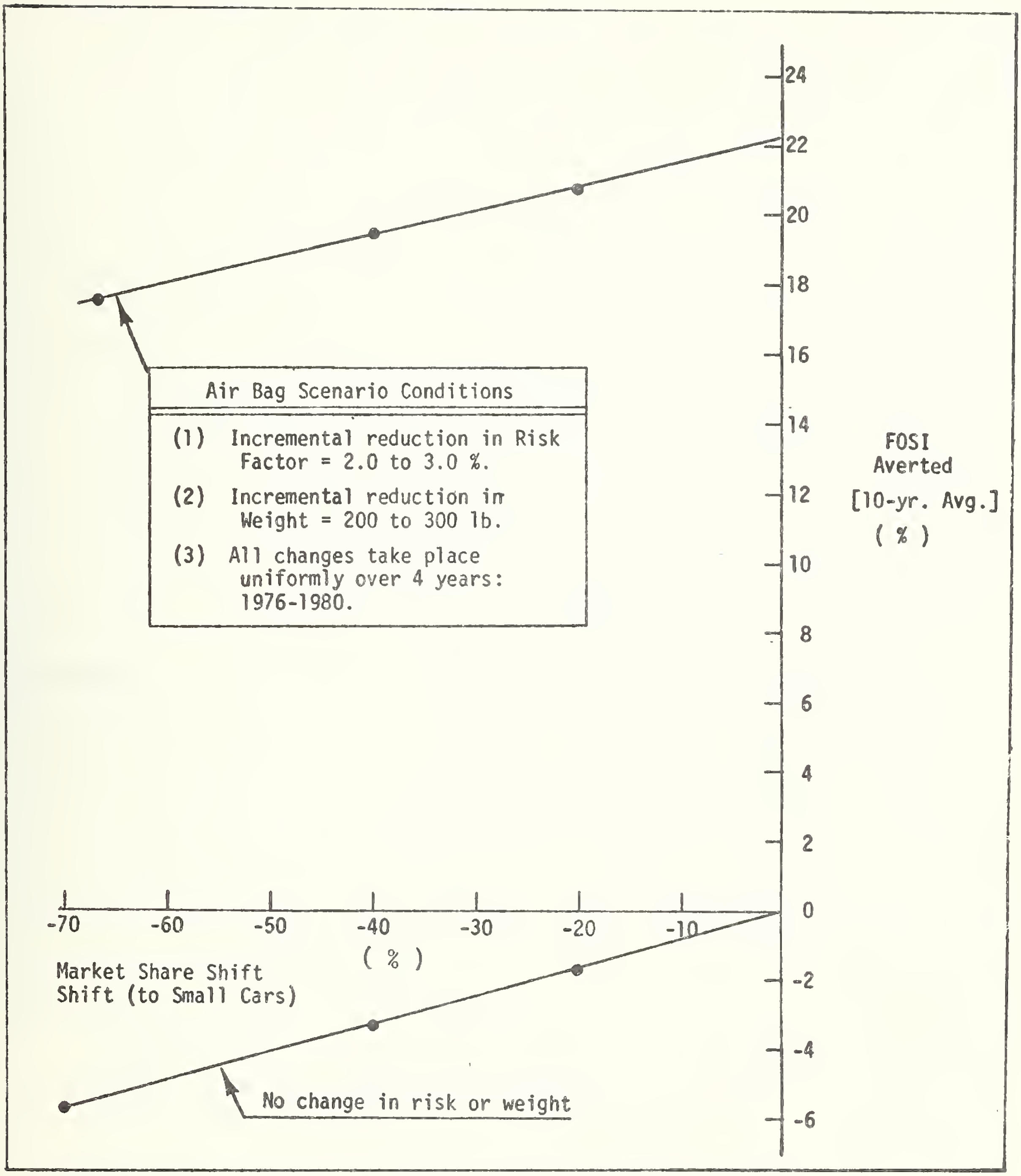


Figure 5-9. Results from Accident Model Scenario #14.

6.0 THE NEW CAR SALES MODEL

6.1 Purpose of the Model

The immediate effects of Title II are that sales of new cars may shift among car models and car classes. Some effects of such shifts may occur immediately or after as short a time as a few months. Consumers may spend different amounts, and dealers' and manufacturers' sales would be immediately affected, (but use of credit will transform the effect on the consumer into an effect continuing over several years). Manufacturers might adjust their emphasis on car classes and models, which might affect production volume after a short time. Any effects of such changes on suppliers will then follow. In the New Car Sales Model, time delays are not considered. Instead, we assume that all changes of this type occur in the same model year. Such changes might affect individual companies in quite different ways: some may be gaining what others are losing. Overall, however, many shifts may cancel out and the net effects may be small. Estimating which manufacturers or dealers might be affected would require knowledge of which cars will finally appear better in Title II information made available to the public. Since we have no way of accurately determining the future of such detailed aspects, we have restricted the model to net effects.

6.2 Background

The societal consequences of changes in the volume and pattern of new car sales can be very great indeed, as the Nation is currently experiencing.

The New Car Sales Model is structured to accommodate four car classes. The Model is run for an eleven year time period from 1975 through 1985. The Model assumes that 1975 model year cars represent all the 1975 and Before cars (i.e., all the Before Title II cars). Model year cars from 1976 through 1985 are considered to be "after Title II" cars.

The Model performs two sets of analyses defined as:

- *Without Title II:* It is assumed that the Market Shares of the four car classes remain constant as new car sales of domestic and foreign cars grow from about 9.8 million in 1975 to about 15.6 million in 1985.

- *With Title II:* It is assumed that the Market Shares of new cars can vary from 1976 through 1985 as a consequence of Title II.

Comparisons of results with and without Title II are made for the ten-year period 1976 through 1985. The societal elements analyzed include the following:

- Consumer expenditures - basic cost of new car and cost of options
- Car Dealers employment and sales margin
- Car Manufacturers employment, and value added
- Suppliers employment, and value added.

The suppliers analyzed provide steel, rubber, aluminum, plastics, paint, lead, copper and glass for the manufacture of new cars.

6.3 Conceptual Outline of the New Car Sales Model

In its simplest outline form, the New Car Sales Model appears as shown in Figure 6-1. Inputs and principal outputs are discussed below. Details of computations are presented in Section 6-4.

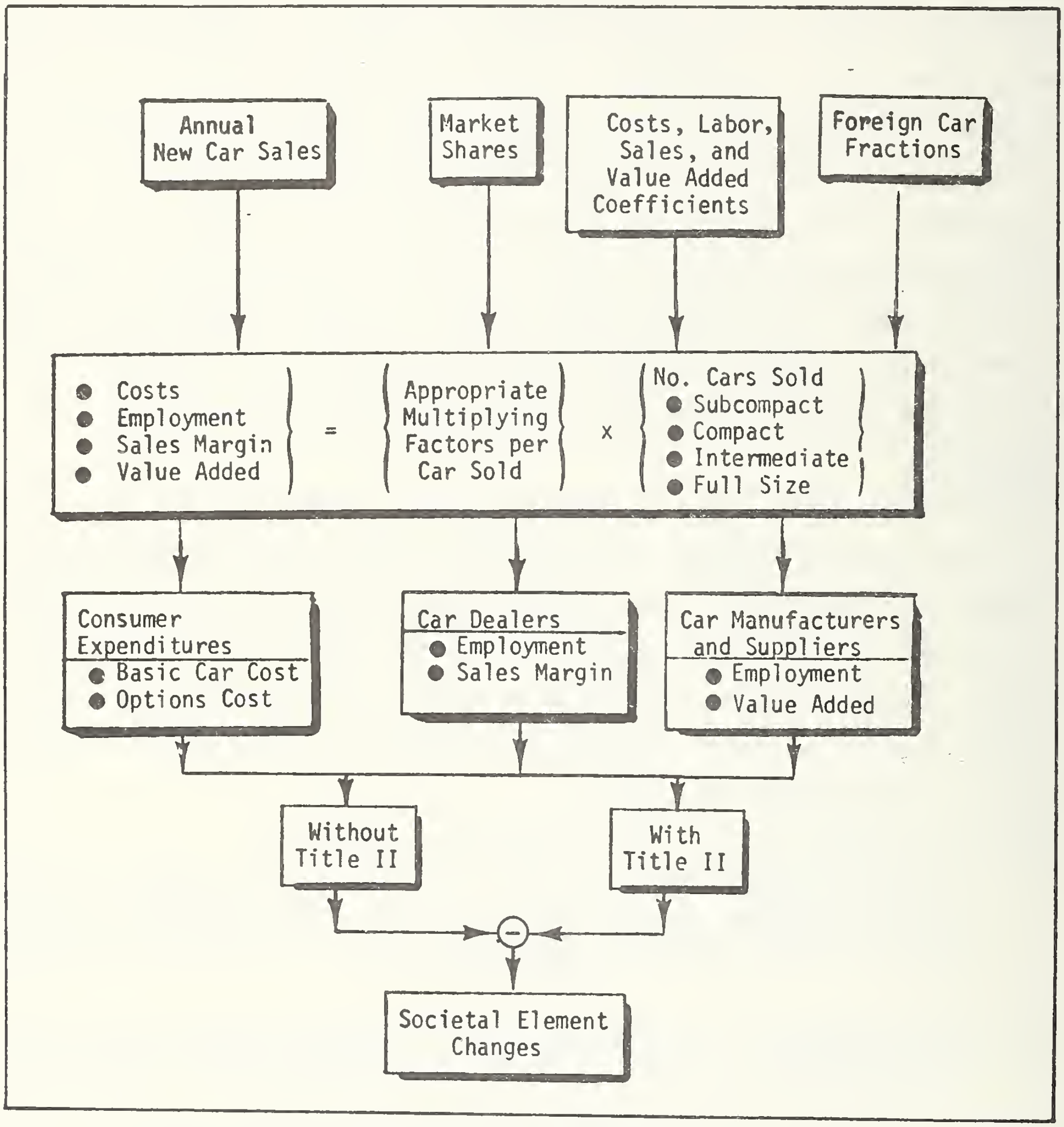


Figure 6-1. The New Car Sales Model.

6.3.1 Inputs

The inputs to the New Car Sales Model are:

- Percentage of Subcompact and Compact new cars produced in the U.S.
  - The percentages are one of the inputs.
- Market Shares for 16 car types for 1975-1985 new car models
  - The Model assumes there will be four cars in each of the four car classes: Subcompact, Compact, Intermediate, and Full Size.*
- Total New Car Sales (domestic and foreign) for 1975-1985
- Coefficients (in appropriate unit per car) for 22 Societal Elements for each of four car classes. The 22 Societal Elements are:
  - Consumer Expenditure: basic cost and option costs
  - Car Dealers - employment and sales margin
  - Car Manufacturers - employment and value added
  - Steel Suppliers - employment and value added
  - Rubber Suppliers - employment and value added
  - Aluminum Suppliers - employment and value added
  - Plastic Suppliers - employment and value added
  - Paint Suppliers - employment and value added
  - Lead Suppliers - employment and value added
  - Copper Suppliers - employment and value added
  - Glass Suppliers - employment and value added.

6.3.2 Outputs

The principal outputs from the Accident Model are:

- Societal Elements Costs, Labor, Sales Margin and Value Added Without Title II
  - The Model assumes that the Market Shares specified for 1975 continue throughout the 1976-1985 period. Societal Element Measures are computed for each of the ten years, summed and the 10-year average is determined.
- Societal Elements Costs, Labor, Sales Margin and Value Added With Title II
  - The Model uses the Market Shares specified for each of the ten years, 1976 through 1985. Thus, the Model can accommodate sudden shifts in Market Shares or gradual changes over several years. Societal Element Measures are computed for each of the ten years, summed and the 10-year averages determined.
- Changes in Societal Elements Costs, Labor, Sales Margin and Value Added Due to Availability of Title II Information
  - The Model computes for each year the difference between Societal Element Measures for the Without Title II condition and the With Title II condition. These are summed and the 10-year average is determined. These data are also presented as a percentage, relative to the Societal Element Measures that would have occurred under the Without Title II condition.

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*A second version of this Model accommodates Market Shares for the four car classes.

6.4 The Structure of the New Car Sales Consequences Model

The New Car Sales Consequences Model is summarized in seven steps shown in Figure 6-2.

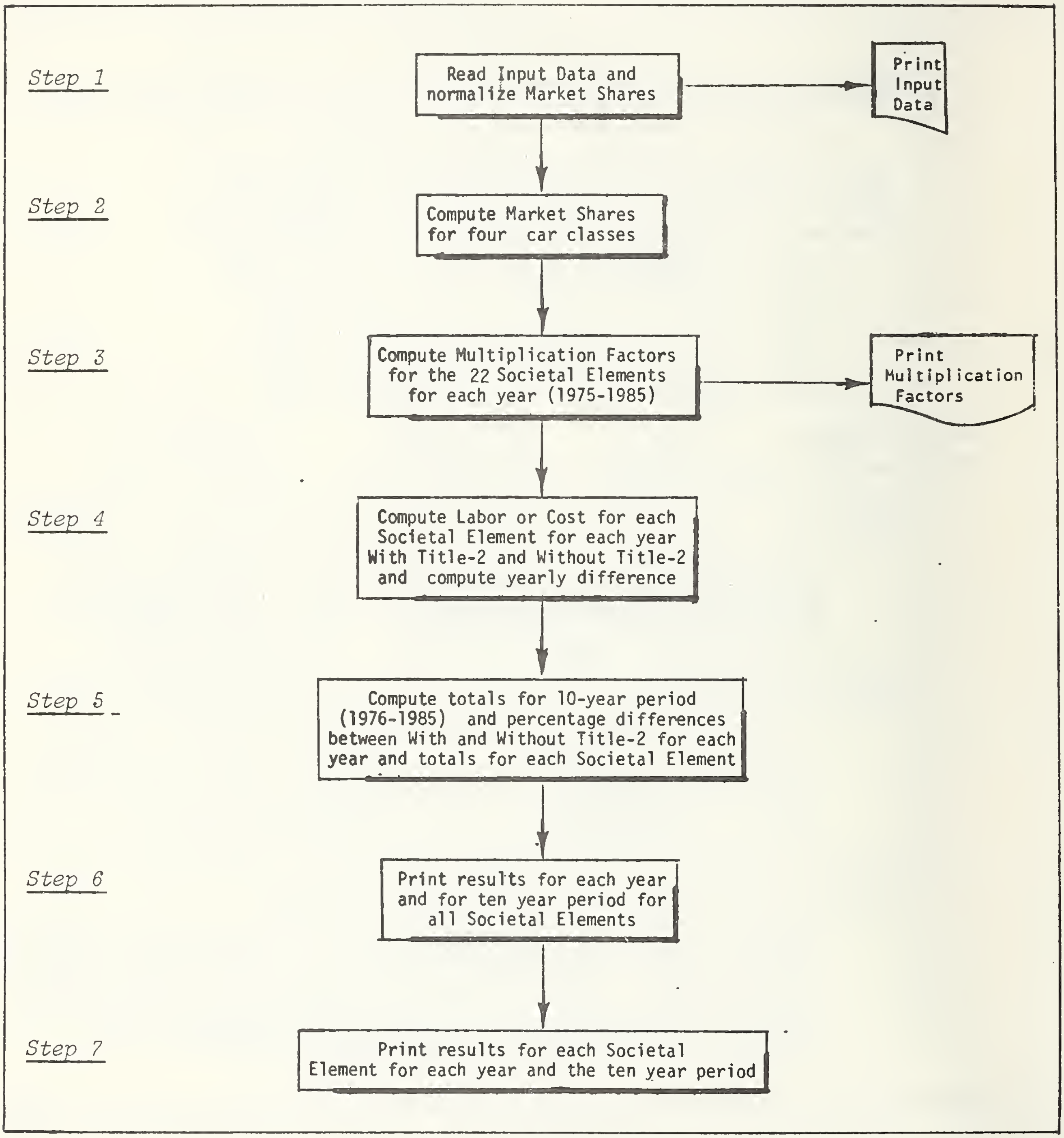

Figure 6-2. Flow diagram for the New Car Sales Model.

The model is described in more detail in the seven steps discussed below.

Step 1

Objective: Read input data and normalize market shares.

Inputs:

- Percent of subcompact and compact domestic cars
- Market Shares (for 1975-1985, by Model Year)
- Total New Car Sales (for 1975-1985)
- Societal Element Coefficients (for 4 car classes)

Computations:

```
DO ## I = 1, 11
DO ## J = 1, 16

SHARE (I,J) = SHARE (I,J)/TOT INPUT SHARES
(normalized)      (input)
```

Comments:

The Subscript "I" refers to years and "J" to car type.

Outputs: The input data and normalized market shares are printed out for completeness and verification of data used.

Step 2

Objective: Compute Market Shares for four car classes.

Input: Market Shares for sixteen car types.

Computations:

```
DO ## I = 1, 11
DO ## K = 1, 4
```

$$SHARE(I,K) = \sum_{J=n}^{m} SHARE\ (I,J),$$

where n = 1, 5, 9, 13

for K = 1, 2, 3, 4

m = 4, 8, 12 16

Output: Market Shares in each of four car classes.

Step 3

Objective: Compute Multiplication Factors for 22 Societal Elements for each year (1975-1985)

Inputs: Societal Element Coefficients, percent of subcompact and compact domestic cars, and Market Shares in four car classes.

Computations:

```
DO  ##  I = 1, 11
DO  ##  L = 1, 22
```

$$MULTFAC(I,L) = \sum_{K=1}^{4} SHARE(I,K)*COEF(L,K)*PCT(K)'$$

Comments:

1. The Subscript "L" refers to Societal Elements.
2. PCT(K), the percent of subcompact and compact domestic cars is $\neq 1$ only if
   (a) $L > 5$ (i.e., manufacturers or suppliers), and
   (b) $I = 1$ or 2 (subcompact or compact).

Output: The Multiplication Factors are printed out.

Step 4

Objective: Compute Labor, Sales Margin and/or Cost (Societal Consequence) for Societal Elements for each year, with and without Title-2 and the difference.

Inputs: Total New Car Sales (1975-1985) and Multiplication Factors.

Computations:

```
DO  ##  I = 1, 11
DO  ##  L = 1, 22

CON(I,L) = MULTFAC(I,L)* NEWCAR(I)
CON2(I,L) = MULTFAC(I,L)* NEWCAR (I)
DIFF(I,L) = CON(I,L) - CON2(I,L)
```

Output: Labor,Sales Margin and/or Cost for Societal Elements for each year for the "Without Title II" and "With Title II" conditions and the difference.

Step 5

Objective: Compute totals for ten year period (1976-1985) and percentage difference

Inputs: Societal consequences with and without Title-2 and differences for 1975-1985.

Computations:

DO ## L = 1, 22

$$CON(12,L) = \sum_{I=2}^{11} CON(I,L)$$

$$CON2(12,L) = \sum_{I=2}^{11} CON2(I,L)$$

$$DIFF(12,L) = \sum_{I=2}^{11} DIFF(I,L)$$

```
DO  ##  I = 1, 12
DO  ##  L = 1, 22
PERC(I,L) = DIFF(I,L)/CON(I,L)*100.
```

Output: Ten year totals "Without Title II" and "With Title II" and percentage difference.

Step 6

Objective: Print for each year and the total for the ten year period,the new car sales societal consequences for the 22 Societal Elements.

Input: Societal consequences with and without Title 2,the differences and percentage differences for 22 elements by year and for the ten year period.

Computations:

```
DO  ##  I = 1, 12
PRINT(CON(I,L),CON2(I,L),DIFF(I,L),PERC(I,L),L = 1, 22)
```

Output: Results for each year and 1976-1985 totals are printed.

Step 7

Objective: Print for each societal element the new car sales consequences for each year and the ten year period.

Input? Societal consequences with and without Title-2,the differences and percentage differences for 22 elements by year and for the ten year period.

Computations:

```
DO  ##  L = 1, 22
PRINT(CON(I,L),CON2(I,L),DIFF(I,L),PERC(I,L), I = 1,12)
```

Output: Results for each Societal Element are printed.

6.5 Characteristics of the New Car Sales Model

With only one input parameter--Market Shares for the four car classes--the output of the New Car Sales Model is directly dependent on the coefficients for the 22 societal elements. The cost, employment, and value added coefficients used in this model are shown in Table 6-1. The coefficients are shown graphically in Figures 6-3, 6-4, and 6-5. As can be seen there are four non-linear weight-dependent functions which characterize basic car cost, the cost of car options, dealer sales margin, and the value added by manufacturers. Of the remaining 18 societal elements, 16 are described by linear monotonic increasing functions of weight. The other two--dealer employment and manufacturers employment--are assumed to be independent of the car weight. (While we know this is not exactly correct, the little information available suggests the difference that may exist is trivially small.)

The analysis leading to the selection of the coefficients in Table 6-1 is given in Appendix E.

TABLE 6-1

COEFFICIENTS FOR 22 SOCIETAL ELEMENTS, AS A FUNCTION OF CAR WEIGHT

Societal Elements	Basic Car and Options Cost, and Dealer Sales Margin ($)				
	Sub-Compact (2200 lb)	Compact (3200 lb)	Inter-mediate (3800 lb)	Full Size (4400 lb)	Average Car (3400 lb)
1. Basic Car Cost	2244	2526	2860	4016	2600
2. Options Cost	285	460	730	327	550
3. Dealer Sales Margin	329	448	610	870	490

Societal Elements	Employees per Thousand Cars Produced and/or Sold				
	Sub-Compact (2200 lb)	Compact (3200 lb)	Inter-mediate (3800 lb)	Full Size (4400 lb)	Average Car (3400 lb)
4. Dealers	17.6	17.6	17.6	17.6	17.6
5. Manufacturers	85.	85.	85.	85.	85.
Suppliers:					
6. - Steel	20.	25.	28.	31.	26.
7. - Rubber	8.5	9.6	10.1	10.8	9.75
8. - Aluminum	1.63	1.72	1.79	1.88	1.75
9. - Plastics	0.43	0.64	0.77	0.90	0.69
10. - Paint	0.71	0.80	0.84	0.90	0.81
11. - Lead	0.25	0.25	0.26	0.26	0.26
12. - Copper	0.78	0.83	0.86	0.91	0.85
13. - Glass	2.62	2.73	2.78	2.87	2.75
Total	137.52	144.17	148.00	152.12	145.46

Societal Elements	Value Added per Car Produced ($)				
	Sub-Compact (2200 lb)	Compact (3200 lb)	Inter-mediate (3800 lb)	Full Size (4400 lb)	Average Car (3400 lb)
14. Manufacturers	674	776	912	1085	821.33
Suppliers:					
15. - Steel	160.90	255.60	312.40	373.90	275.00
16. - Rubber	60.70	80.13	90.91	103.03	82.00
17. - Aluminum	19.03	22.41	24.53	26.64	23.30
18. - Plastics	2.12	7.12	10.20	13.28	8.10
19. - Paint	7.01	8.98	10.10	11.39	9.30
20. - Lead	2.74	2.90	2.98	3.05	2.93
21. - Copper	8.37	9.97	10.86	11.75	10.25
22. - Glass	30.58	33.36	34.96	36.54	33.75
Total	965.45	1196.47	1408.94	1664.58	1265.96

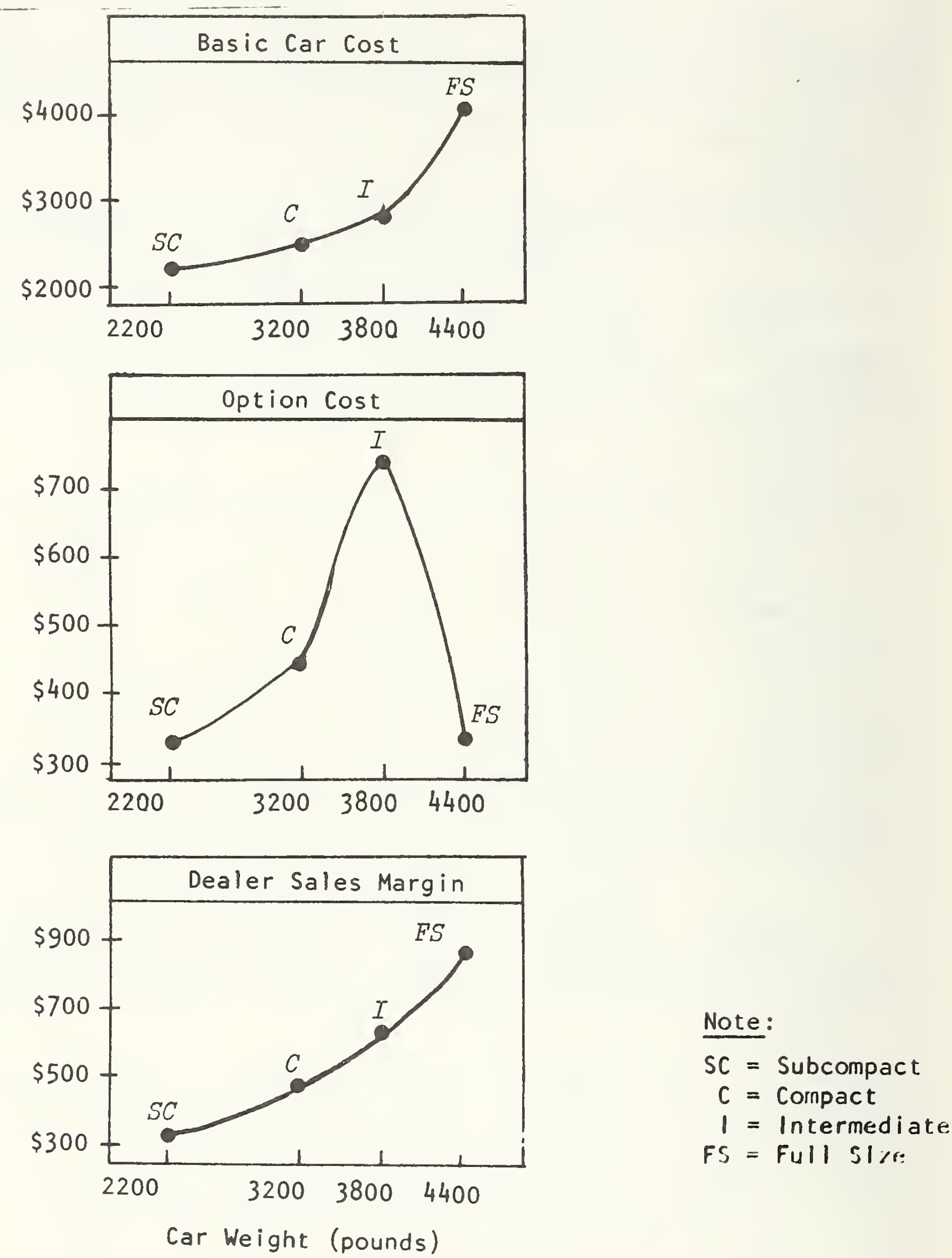

Figure 6-3. Basic car and options cost, and dealer sales margin.

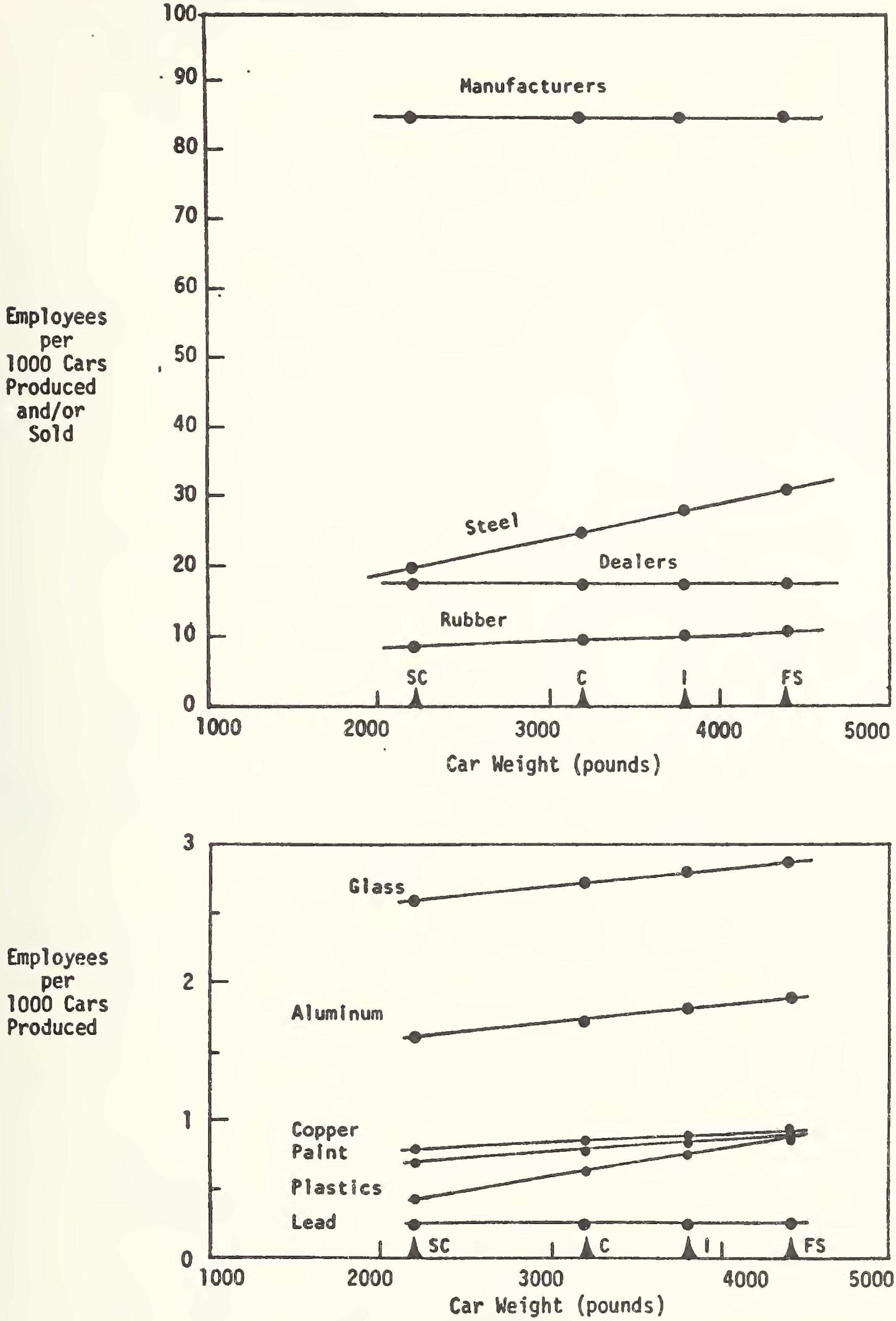

Figure 6-4. Employment for automobile dealers, manufacturers, and suppliers.

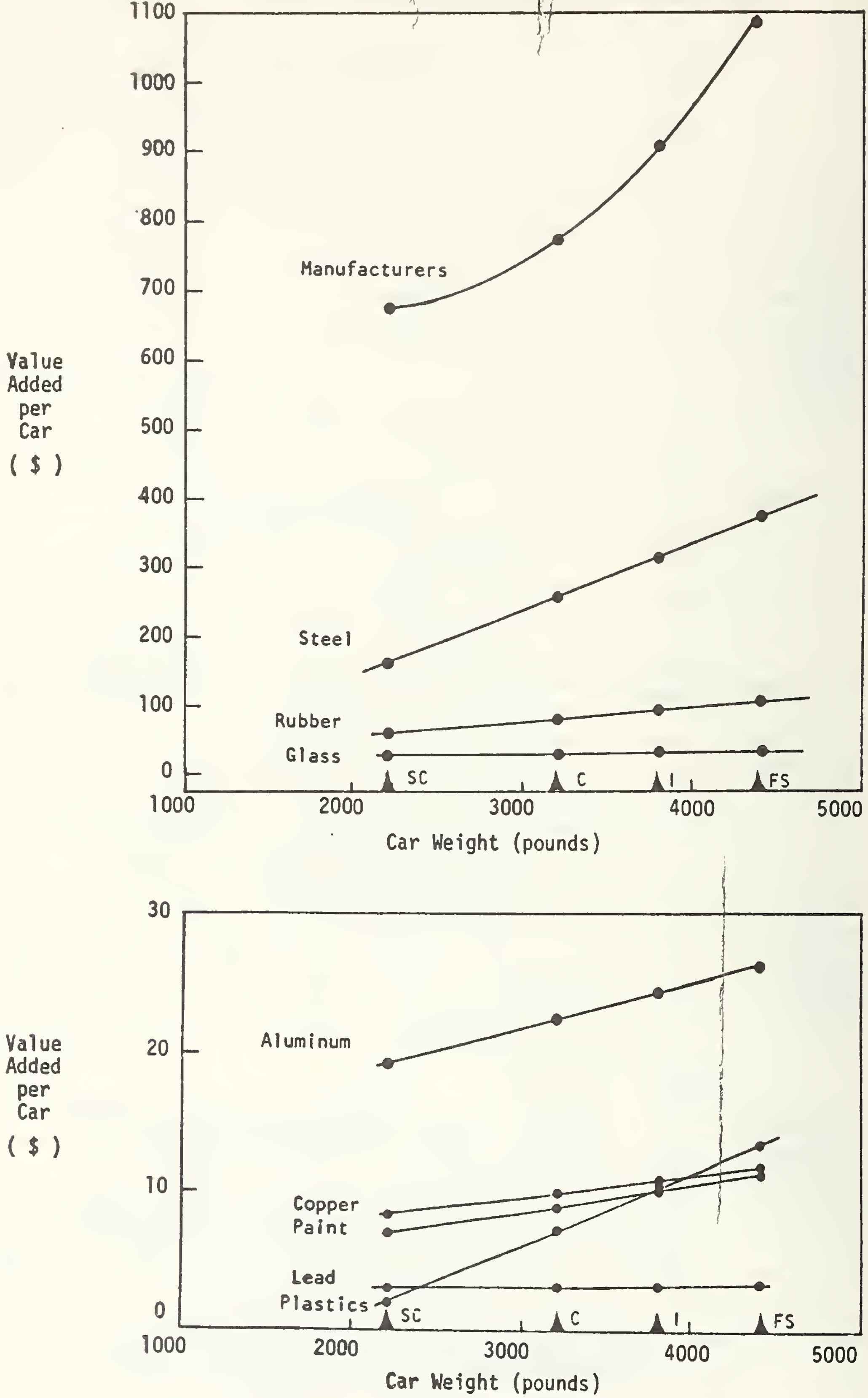

Figure 6-5. Value added for automobile manufacturers and suppliers.

6.6 Sensitivity of the New Car Sales Model

The New Car Sales model is a linear model in response to the magnitude of changes in Market Shares. That is, if a Market Share Shift of 10 percent up to large cars increases the consumer expenditure for cars by 2 percent, then a Market Share Shift of 20 percent will double the increase in consumer expenditure for cars to 4 percent. Also, a "mirror image" Market Share Shift down to small cars of 10 percent would produce a 2 percent reduction in consumer expenditure for cars.

Figure 6-6 illustrates the above general statements with actual data from the New Car Sales Model. Responses to two conditions are shown in the figure: one for the case where the Market Share Shifts take place abruptly in 1976 and remain fixed through 1985, and the other for the case where the Market Share Shift takes place gradually between 1976 and 1979 (4 years) and then continues unchanged through 1985. As would be expected, the gradual shift has less impact on consumer expenditure for the basic cost of cars than the abrupt shift, but they differ by only 12.4 percent.

All of the data in Figure 6-6 are for "uniform" or "balanced" Market Share Shifts, where equal amounts of the total market are taken from the two classes of large cars and given in equal amounts to the two classes of small cars (or vice-versa). Unbalanced Market Share Shifts of the same amount would have produced somewhat different results.

Table 6-2 shows data for all 22 of the societal elements in the New Car Sales Model for a Market Shift of 20 percent for both the abrupt and gradual changes described above. The table (and Figure 6-6, which is representative of the type of response of all the societal elements) indicates that, in general, the various societal elements are not extremely sensitive to small changes in the buying characteristics of the public. For example, in no case does a 1 percent change in Market Shares cause an equal or greater percentage change in a societal element. *Indeed, all changes are less than 0.5 percent change in a societal element per 1 percent change in Market Share Shift.* Thus, even a 10 percent Market Share Shift due to the availability of Title II information will create 5 percent or less change in consumer expenditures for cars and options, employment, dealer sales margin, and value added for manufacturers and suppliers.

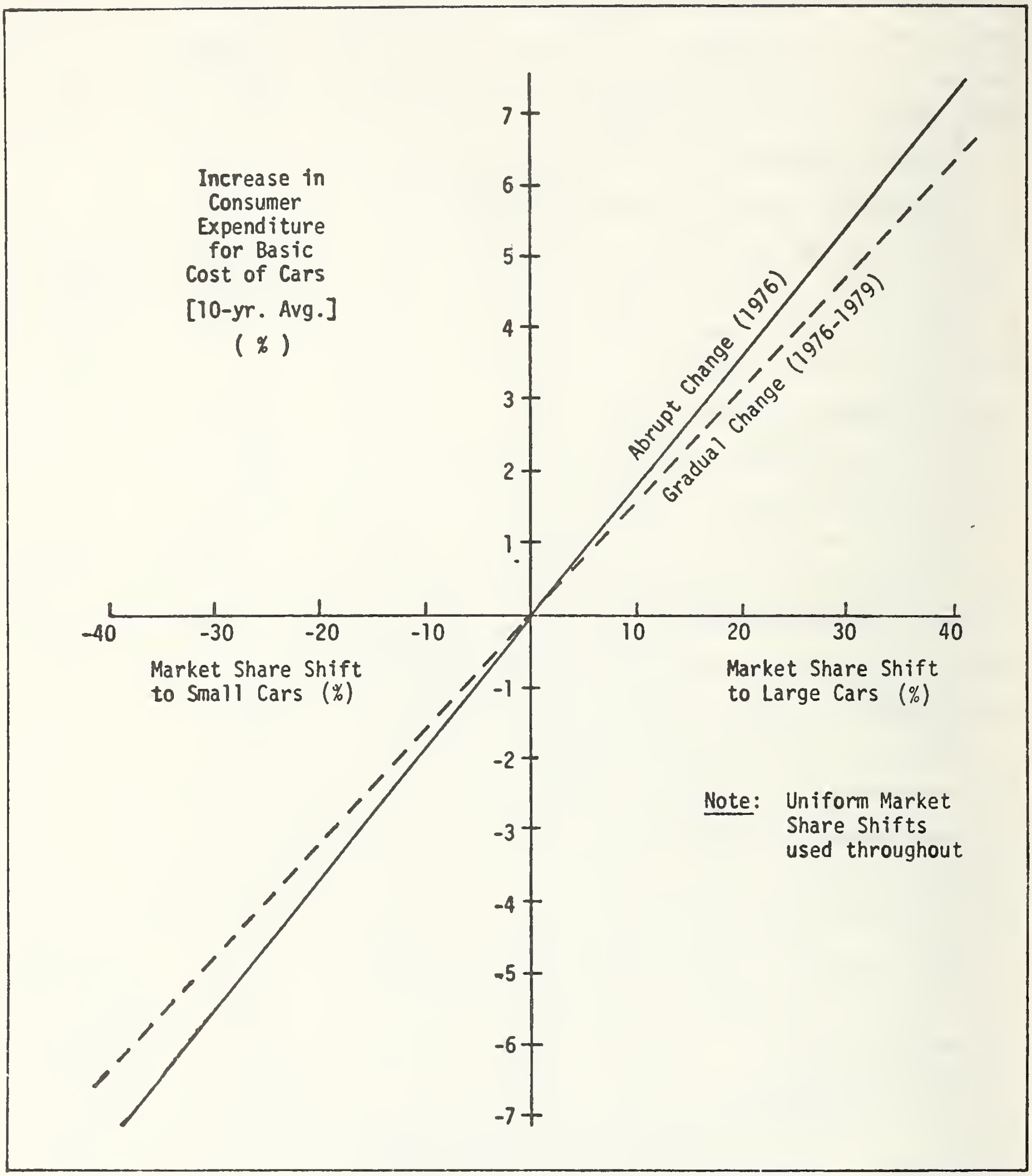

Figure 6-6. Increase in consumer expenditure for the basic cost of cars, as a function of uniform Market Share Shifts.

According to the model, the four industries most sensitive to Market Share Shifts are plastic suppliers, steel suppliers, car dealers, and car manufacturers, in that order. The next four, in order, are rubber suppliers, paint suppliers, aluminum suppliers, and copper suppliers. They are followed by glass and lead suppliers.

TABLE 6-2

COMPARISON OF THE IMPACT OF MARKET SHARE SHIFTS ON 22 SOCIETAL ELEMENTS

Societal Element	Increase Due to 20% Market Share Shift to Large Cars	
	Abrupt Change (1976)	Gradual Change (1976-1979)
Consumer Expenditures:		
1. Basic Car Cost	3.63%	3.18%
2. Options Cost	3.08	2.70
Employment:		
3. Dealers	0.0	0.0
4. Manufacturing	3.41	2.99
5. Steel Suppliers	5.54	4.86
6. Glass Suppliers	3.86	3.38
7. Rubber Suppliers	4.56	4.00
8. Aluminum Suppliers	4.18	3.66
9. Plastics Suppliers	6.80	5.96
10. Paint Suppliers	4.55	3.99
11. Lead Suppliers	3.76	3.30
12. Copper Suppliers	4.20	3.68
Sales Margin:		
13. Dealers	6.13	5.37
Value Added:		
14. Manufacturing	6.09	5.34
15. Steel Suppliers	7.18	6.29
16. Rubber Suppliers	5.90	5.18
17. Aluminum Suppliers	5.10	4.47
18. Plastics Suppliers	9.73	8.53
19. Paint Suppliers	5.73	5.03
20. Lead Suppliers	3.95	3.46
21. Copper Suppliers	5.07	4.44
22. Glass Suppliers	4.31	3.78

One cautionary note to the reader: In this model, the base for employment in the industries supplying car manufacturers is that fraction of total employment in the industry which produces goods used by car manufacturers. Thus, when we refer to "percentage changes in employment," we are referring to percentage changes in the fraction of employment in the industry which supplies car manufacturers, not a percentage of all employees in the industry. This means that a 10 percent change in employment due to the availability of Title II information generally means less than 1.5 percent change in the supplying industry cited, because in no case is more than about 15 percent of the employment in a supply industry engaged in producing materials used by car manufacturers.*

*To be explicit, the fractions of employment serving car manufacturers are: Steel, 15.2 percent; rubber, 14.0 percent; aluminum, 10 percent; plastics, 2 percent; paint 9.1 percent; lead, 7 percent; copper, 9 percent; and glass, 15.4 percent.

These figures are based on the input-output table of U.S. production and consumption in 1967, prepared by the Bureau of Economic Analysis, Department of Commerce.

7.0 THE CAR OPERATIONS COST MODEL

7.1 Purpose of the Model

Use of a car has, aside from accident fatalities and injuries, which are treated in the Accident Model, the following effects: consumption of gasoline, crash repair, routine maintenance and repair, and insurance costs. These effects continue over the lifetime of a car, the average being about 11 years. Most of these effects do not affect model specific manufacturers, except repairs by authorized dealers and the supply of original replacement parts. Most effects are by their nature imposed primarily by the individual owner-operators of passenger cars, and the service stations, repair facilities, and insurance companies which provide these operational needs. Therefore, the Car Operations Model provides results on an aggregate basis.

7.2 Background

The societal consequences of changes in the cost of operating a car can be rather significant,as we are presently finding with increasing prices for gasoline, car repairs, and insurance.

In the Car Operations Cost Model, four elements of societal costs of maintaining and operating a car are considered:

- Gasoline Consumption Costs
- Crash Repair Costs
- Routine Maintenance and Repair Costs
- Cost of Insurance Premiums

Rates in each of these classes are input or computed for up to 16 car types and are age dependent in eleven categories ranging from new cars (0-years old) through all cars ten years or older.* In computing gasoline consumption costs, the following factors are considered: engine efficiency, car mileage as a function of age ,and differences in gasoline consumption rates among car types. Insurance premiums are separated into collision and liability costs, and the former is input and computed as a function of age of car and car type. Liability cost is assumed constant for all car types and ages.

Because the Model is age-dependent, the car population for the calendar years 1975-1985 must include model years from 1965 through 1985 (i.e., 21 model years). The Model assumes that all 1975 and earlier model year cars

*Another version of the Car Operations Model accommodates data inputs for four car classes: Subcompact, Compact, Intermediate and Full Size.

represent "Before Title II" cars. Model year cars from 1976 through 1985 are considered to be "After Title II" cars.

The Model performs two sets of analyses defined as:

- *Without Title II:* It is assumed that 1975 Market Shares for the 16 cars remain constant as the car population grows from about 95 million in 1975 to 138 million in 1985.
- *With Title II:* It is assumed that the Market Shares of new cars from 1976 through 1985 can vary as a consequence of Title II.

Comparisons of results with and without Title II are made for the ten-year period 1976 through 1985.

7.3 Conceptual Outline of the Car Operations Cost Model

In its simplest form, the Car Operations Cost Model appears as shown in Figure 7-1. Inputs and principal outputs are discussed below. Details of computations are presented in Section 7.4.

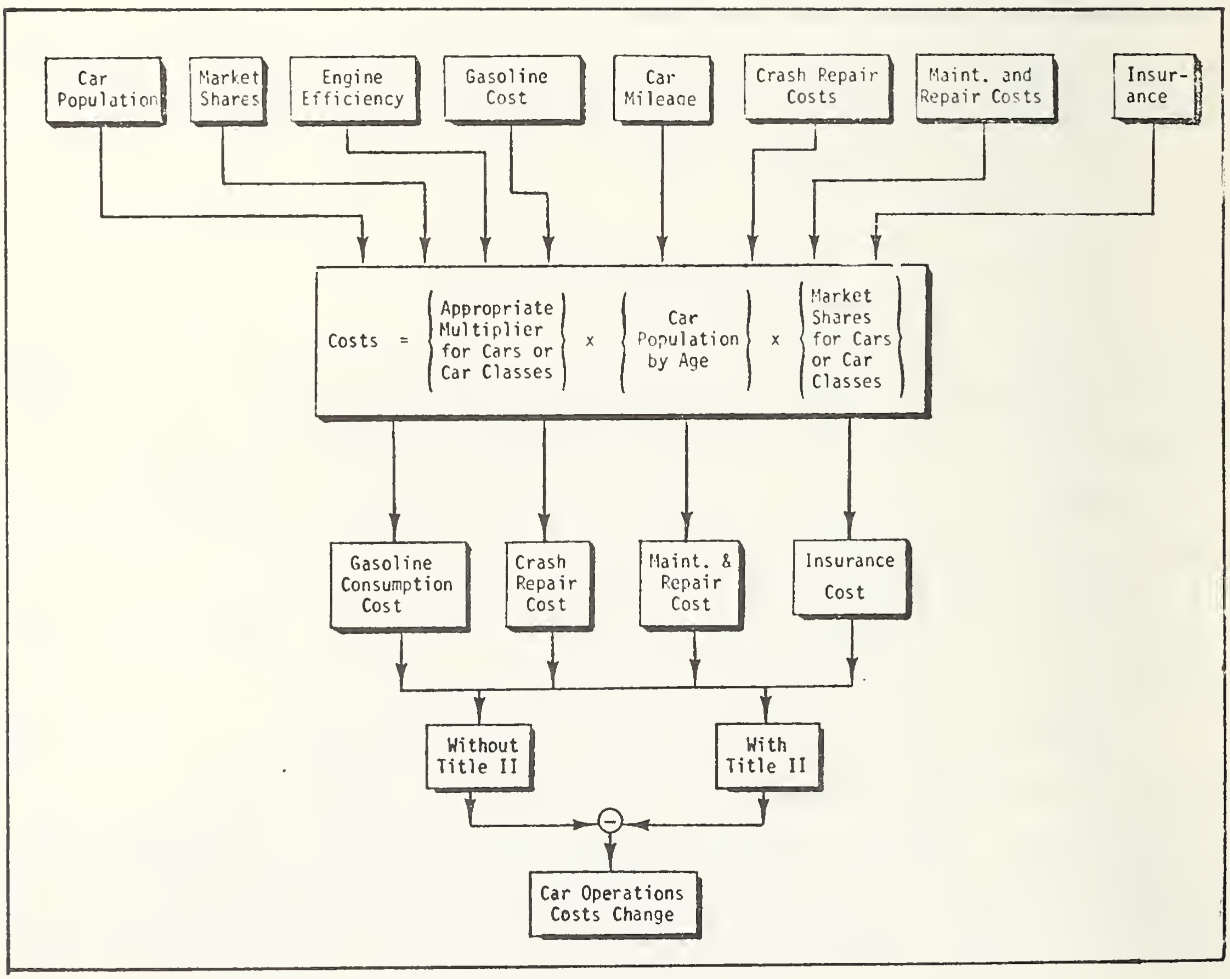

Figure 7-1. The Car Operations Cost Model

7.3.1 Inputs

The inputs to the Car Operations Cost Model are:

- Engine Efficiency
  - 100% for a new car (0-years old) and percentage values less than or equal to 100 for older cars (i.e., 90% efficient when 10 years old)
- Market Shares for 16 Cars (or 4 Car Classes)
  - The Market Shares for Model Year 1965 (and earlier) through Model Year 1985
  - The Market Shares for Model Years 1965 through 1975 are held constant. (This is not a requirement of the program; they could be varied if this was desirable.)
- Number of Registered Cars (Car Population)
  - For Calendar Years 1975 through 1985 by Model Year 1965 (or earlier) through 1985
- Gasoline Cost per mile for 16 Cars
- Average Car Mileage by Age of Car
  - For cars in 11 age categories ranging from new to ten or more years old
- Crash Repair Costs per Year Per Car for 16 Cars
  - For 11 age categories
- Routine Maintenance and Repair Costs per Year per Car for 16 Cars
  - For 11 age categories
- Collision Insurance Factors for 11 Age Categories and 16 Cars

7.3.2 Outputs

The principal outputs from the Car Operations Cost Model are:

- Gasoline Consumption, Crash Repair, Maintenance and Repair and Insurance Costs Without Title II.
  - The Model assumes that the Market Shares specified for 1975 and Before continue throughout the 1976-1985 period. Car operations costs are computed for each of the ten years, summed and the 10-year average is determined.
- Gasoline Consumption, Crash Repair, Maintenance and Repair and Insurance Costs With Title II
  - The Model uses the Market Shares specified for each of the ten years: 1976 through 1985. Thus the Model can accommodate sudden shifts in Market Shares or gradual changes over several years. Car operations costs are computed for each of the ten years, summed and the 10-year average is determined.
- Changes in Costs of Gasoline Consumption, Crash Repair, Maintenance and Repair and Insurance due to Availability of Title II Information.
  - The Model computes for each year the difference between car operations costs for the Without Title II condition and the With Title II condition. These are summed, the differences are computed, and the 10-year averages are determined. These data are also presented as a percentage, relative to the car operations costs that would have occurred under the Without Title II condition.

7.4 The Structure of the Car Operations Model

The Car Operations Model is summarized in seven steps shown in Figure 7-2.

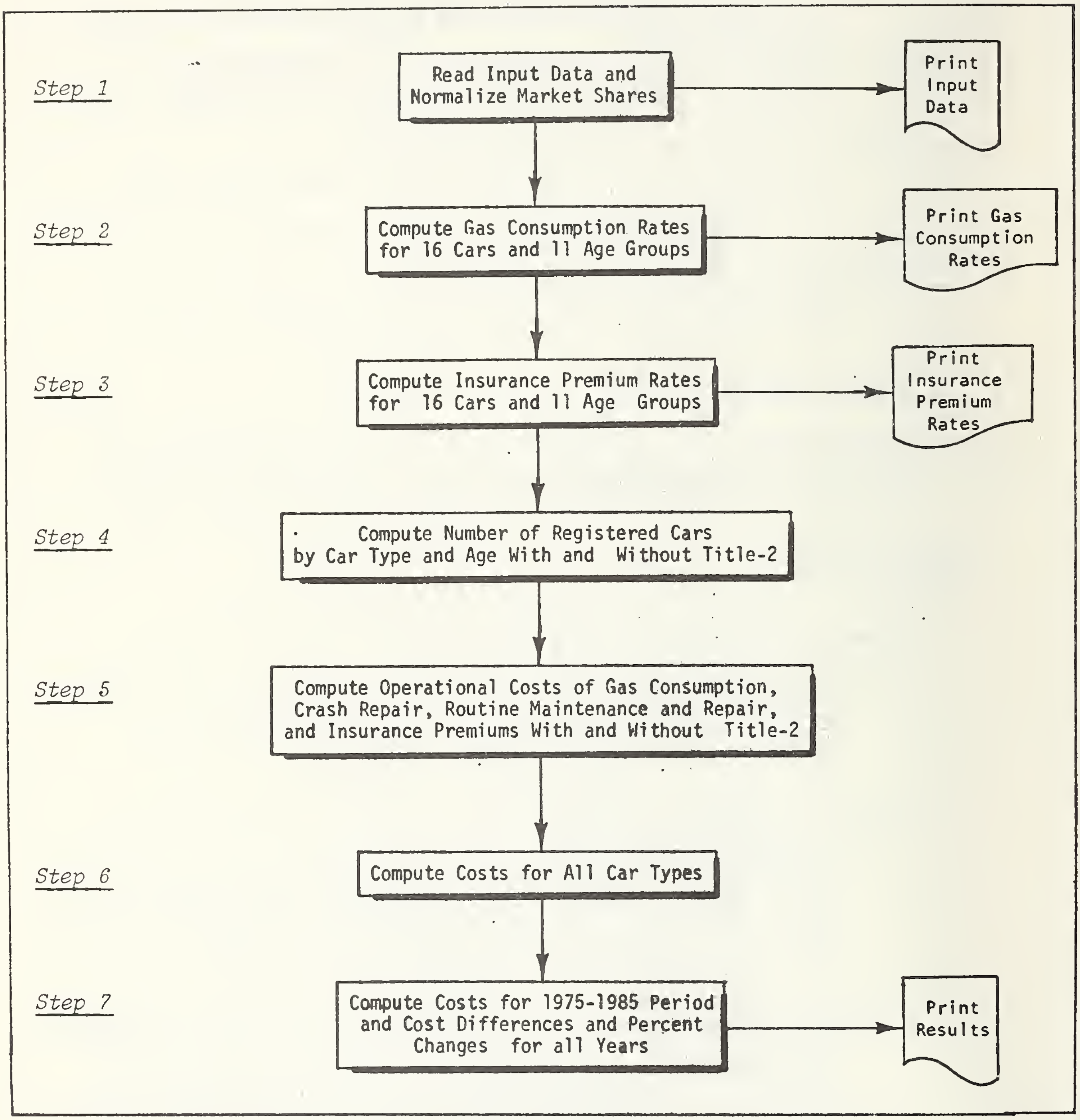

Fig. 7-2. Flow Diagram for the basic Car Operations Cost Model.

The model is described in more detail in the seven steps discussed below.

Step 1

Objective: Read input data and normalize market shares.

Inputs:

- Engine Efficiency
- Market Shares (for 1965-85 Model Years)
- Number of Registered Cars (for 1975-85 Calendar Years and 1965*-85 Model Years)
- Gasoline Cost (for 16 Cars)
- Car Mileage (for 11 Age Categories)
- Crash Repair Costs (for 16 Cars by 11 Age Categories)
- Routine Maintenance (for 16 Cars by 11 Age Categories)
- Collision Insurance Factors for 11 Age Categories
- Collision Insurance Factors for 16 Cars

Computations:

```
DO  ##  L = 1, 21
DO  ##  J = 1, 16

SHARE, (L,J) = SHARE(L,J)/TOT INPUT SHARES
(normalized)    (input)
```

Comments:

The Subscript "L" refers to model years and "J" to car type.

Outputs: The input data and normalized shares are printed out for completeness and verification of data used.

Step 2

Objective: Compute gas consumption rates for 16 car types & 11 age groups.

Inputs:

- Engine Efficiency
- Gasoline Cost for 16 Cars (cost of gasoline is $0.50/gal)
- Car Mileage (for 11 Age Categories)

Computations:

```
DO  ##  J = 1, 16
DO  ##  K = 1, 11

GASRATE(J,K) = GAS(J)*MILEAGE(K)/ENGEFF(K)
```

Comments: The Subscript "K" refers to car age.

Output: The gas consumption rates are printed out.

---
* Throughout, all references to "1965" mean "1965 and before."

Step 3

Objective: Compute insurance premium rates for 16 car types and 11 age groups.

Inputs:
- Insurance Premium Factor for 16 Cars
- Insurance Premium Factor for 11 Age Categories

Computations:

```
DO ## J = 1, 16
DO ## K = 1, 11
INSRATE(J,K) = 76.*INSTYP(J)*INSAGE(K) + 120.
```

Output: The insurance premium rates are printed out.

Step 4

Objective: Compute number of registered cars by car type and age With and Without Title II.

Input:
- Number of Registered Cars (for Calendar Years 1975-1985 and Model Years 1965-1985)
- Market Shares (for Model Years 1965-1985)

Compilations:

```
DO ## I = 1, 11
IL = I
NL = I + 10
DO ## L = IL, NL
DO ## J = 1, 16
CARTYP1(I,L,J) = CARS (I,L)*SHARE(11,J)
CARTYP2(I,L,J) = CARS (I,L)*SHARE(L,J)
```

Comments:

The Subscript "I" refers to calendar years.

Output: Number of registered cars by 16 types and 11 age categories for each year, With and Without Title II.

Step 5

Objective: Compute operational costs of gas consumption, crash repair, routine maintenance and repair, and insurance premiums With and Without Title II.

Inputs:

- Gasoline Consumption Rates for 16 Cars and 11 Ages
- Insurance Premium Rates for 16 Cars and 11 Ages
- Crash Repair Rates for 16 Cars and 11 Ages
- Routine Maintenance & Repair Rates for 16 Cars and 11 Ages
- Number of Registered Cars by Car Type and Age for each Calendar Year (1975-1985)

Computations:

```
DO ## I = 1, 11
IL = I
NL = I + 10
DO ## J = 1, 16
```

$$GASOL1(I,J) = \sum_{L=IL}^{NL} CARTYP1(I,L,J)*GASRATE(J,IM)$$

$$INSUR1(I,J) = \sum_{L=IL}^{NL} CARTYP1(I,L,J)*INSRATE(J,IM)$$

$$CRASH1(I,J) = \sum_{L=IL}^{NL} CARTYP1(I,L,J)*CRHRATE(J,IM)$$

$$MAINT1(I,J) = \sum_{L=IL}^{NL} CARTYP1(I,L,J)*MAIRATE(J,IM),$$

where, in each equation,

$$IM = I-L+11$$

Comments:

The above equations compute the costs of gasoline, insurance, crash repairs and routine maintenance for the Without Title II car population distribution. An analogous set of equations computes these costs for the With Title II car population by replacing the variable CARTYP1 with CARTYP2.

Output: Costs of gas consumption, crash repair, maintenance and repair and insurance for each year, With and Without Title II by car type.

Step 6

Objective: Compute costs for all car types.

Inputs: Cost of gasoline consumption, insurance premiums, crash repair, and routine maintenance and repair for 16 car types and 11 Calendar Years.

Computations:

DO ## I = 1, 11

$$GASOL1(I,17) = \sum_{J=1}^{16} GASOL1(I,J)$$

$$INSUR1(I,17) = \sum_{J=1}^{16} INSUR1(I,J)$$

$$CRASH1(I,17) = \sum_{J=1}^{16} CRASHi(I,J)$$

$$IAINT1(I,17) = \sum_{J=1}^{16} MAINT1(I,J)$$

Comments:

Analogous equations are used for the With Title II situation by replacing GASOL1 with GASOL2, etc.

Output: Car Operations Costs for all car types summed, With and Without Title II.

Step 7

Objective: Compute With and Without Title II costs for calendar years 1975-1985 and cost differences and percentage differences for all years.

Inputs: Cost of gasoline consumption, insurance premiums, crash repair, and routine maintenance and repair for 16 and all car types by 11 calendar years.

Computations:

```
DO ## J = 1, 17
```

$$GASOL1(12,J) = \sum_{I=2}^{11} GASOL1(I,J)$$

$$INSUR1(12,J) = \sum_{I=2}^{11} INSUR1(I,J)$$

$$CRASH1(12,J) = \sum_{I=2}^{11} CRASH1(I,J)$$

$$MAINT1(12,J) = \sum_{I=2}^{11} MAINT1(I,J)$$

```
DO ## I = 1, 12

GASDIF(I) = GASOL1(I,17) - GASOL2(I,17)
INSDIF(I) = INSUR1(I,17) - INSUR2(I,17)
CRHDIF(I) = CRASH1(I,17) - CRASH2(I,17)
MAIDIF(I) = MAINT1(I,17) - MAINT2(I,17)

DO ## I = 1, 12

GASPCT(I) = GASDIF(I)/GASOL1(I,17)*100.
INSPCT(I) = INSDIF(I)/INSUR1(I,17)*100.
CRHPCT(I) = CRHDIF(I)/CRASH1(I,17)*100.
MAIPCT(I) = MAIDIF(I)/MAINT1(I,17)*100.
```

Comments:

The first set of the above calculations are also performed for With Title II by replacing GASOL1 with GASOL2, etc.

Output: All results are printed out.

7.5 Characteristics of the Car Operations Model

Like the New Car Sales Model, the Car Operations Model has only one major input parameter: Market Shares for cars purchased from 1976 through 1985. The model has been designed to accommodate Market Shares for 16 cars (4 cars in each of 4 car classes), or 4 car classes. Inputs such as engine efficiency and the car population can be varied, if desired. However, in this study no changes were made in these parameters.

Figures 7-3, 7-4, 7-5, and 7-6 show, as a function of car age, typical curves for the salient features of this model:

- Annual cost of the consumption of gasoline
- Annual cost of crash repair
- Annual cost of routine maintenance and repair
- Annual cost of insurance.

The annual cost of gasoline consumption (Figure 7-3) is primarily a function of VMT and engine efficiency, which we assume diminishes at a linear rate of 1 percent per year after the first year of operation. As a rough rule of thumb, the annual cost of gasoline consumption (i.e., car usage) reduces by a factor of about one-half over the 11-year lifetime of the car with most of the reduction taking place in the first four years.

The annual cost of crash repair (Figure 7-4) diminishes by a factor of somewhat more than one-half over the lifetime of the car. This reflects miles driven each year, changes in ownership, and a common characteristic: when minor crash damage occurs, older cars are not as likely to be repaired as newer cars.

The annual cost of routine maintenance and repair (Figure 7-5) tends to peak in about the sixth or seventh year of operation. About this time the car has accumulated about 50,000 to 70,000 miles and is in need of a major engine and/or drive train overhaul. Beyond the ninth or tenth year, maintenance and repair drops off abruptly, in part probably because the car is driven much less and/or the owner performs the work himself.

The annual cost of insurance (Figure 7-6) diminishes very little during the first seven years of car operation. Beyond that point, many insurance firms refuse to offer collision insurance, because the resale value of many cars is so low by that age. The cost of liability insurance ($120/year) is assumed to be constant for all cars throughout their lifetime.

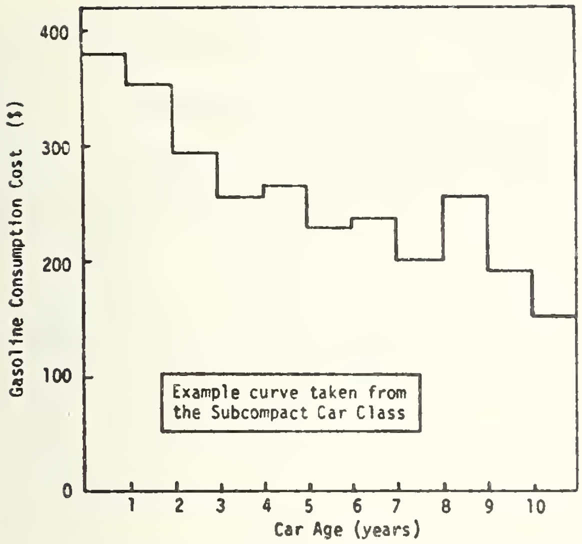

Figure 7-3. Example of the annual cost of gasoline consumption as a function of car age.

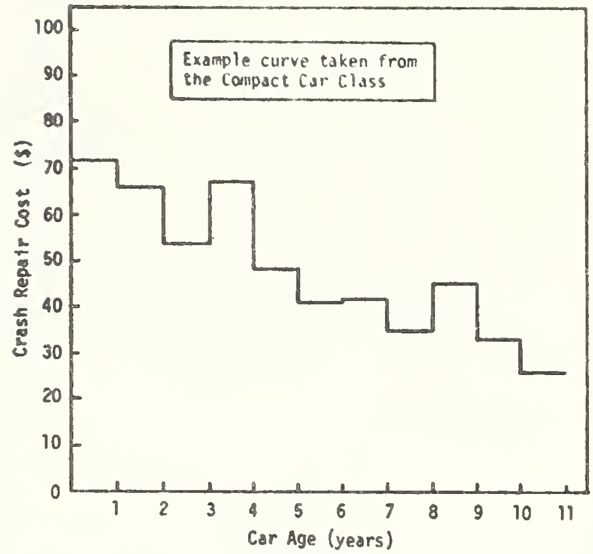

Figure 7-4. Example of the annual cost of crash repair as a function of car age.

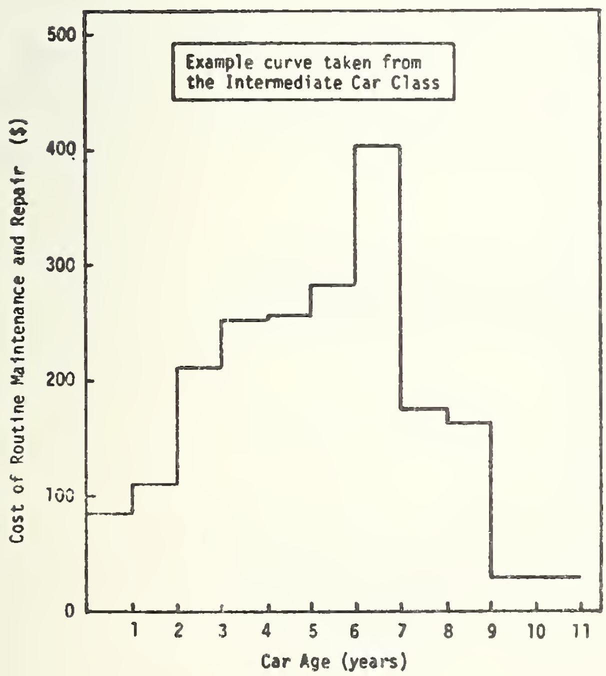

Figure 7-5. Example of the annual cost of routine maintenance and repair, as a function of car age.

Figure 7-6. Example of the annual cost of insurance as a cost of insurance as a function of car age.

In general, the cost of operating a car increases directly in proportion to increase in car weight. There is, however, one major exception to that rule. The annual cost of crash repair is greater for subcompacts than for larger cars, because when subcompacts crash with larger cars, they sustain greater damage, and until recently subcompacts have had much less bumper protection, so that even minor front or rear accidents could result in major structural damage.

The analyses providing the necessary car operations data for this model are described in Appendix F.

7.6 Sensitivity of the Car Operations Model

As was the case with the New Car Sales Model, the Car Operations Model does not show a high level of sensitivity to shifts in Market Shares, which might occur as a function of the availability of Title II information. This model, too, is a linear model, in the sense that a doubling of a given Market Share Shift produces a doubling of the percent change in the cost of car operations.

Figure 7-7 shows the sensitivity of the four car operations elements to "uniform" changes in Market Share Shift, where equal amounts of the total market are being taken from Subcompact and Compact cars and are being given in the same equal amounts to Intermediate and Full Size cars. The solid straight lines show the response of the elements to Market Share Shifts which begin abruptly in 1976 and continue through 1985. The dashed line shows that if the same Market Share Shift is achieved gradually during 1976-1979 and then continued through 1985, the impact is about 20 percent less for the cost of gasoline consumption.

Table 7-1 provides data for the four car operations societal elements for the case of an abrupt 30 percent Market Share Shift to large cars, and the case for a gradual 30 percent Market Share Shift to large cars. Uniform Market Share Shifts were used in both instances. Gasoline consumption is the most sensitive societal element in this group, increasing about 0.17 percent for each one percent increase in Market Share Shift to large cars,

TABLE 7-1

COMPARISON OF THE IMPACT OF MARKET SHARE SHIFTS ON FOUR CAR OPERATIONS SOCIETAL ELEMENTS

Societal Element	Increase Due to 30% Market Share Shift to Large Cars	
	Abrupt Change (1976)	Gradual Change (1976-1979)
1. Cost of Gasoline Consumption	5.1%	4.08%
2. Cost of Crash Repair	- 1.34%	- 1.08%
3. Cost of Routine Maint. & Repair	1.02%	0.78%
4. Cost of Insurance	0.42%	0.35%

Note: Percentages are 10-year average values.

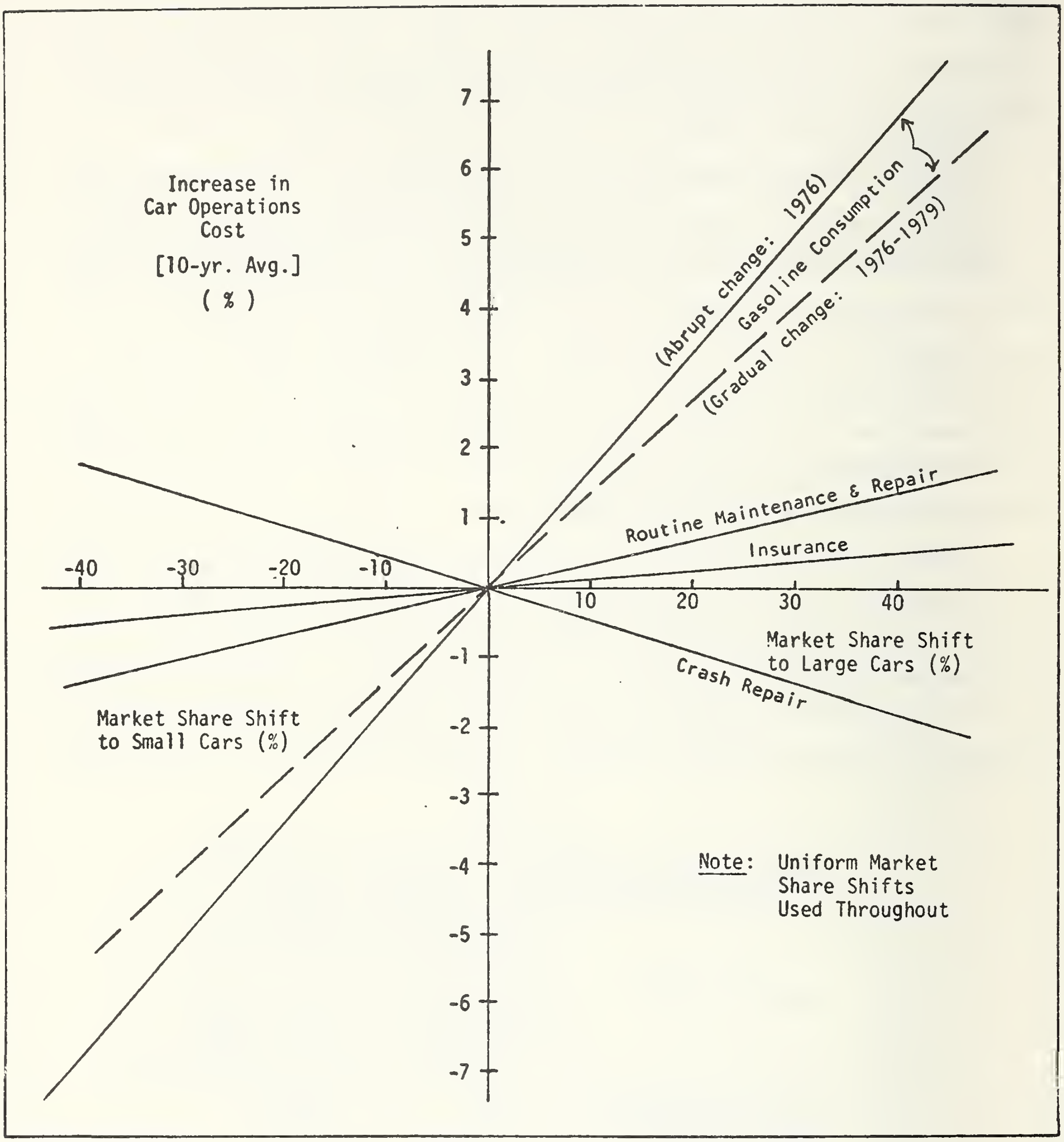

Figure 7-7. Increase in car operations cost, as a function of uniform Market Share Shifts.

assuming the change takes place abruptly in 1976 and is continued. (If the change takes place gradually, then the increase would be about 0.14 percent for each 1 percent increase in Market Share Shift.) Rates of change for the other car operations societal elements are - 0.44 percent/percent for crash repair; 0.34 percent/percent for routine maintenance and repair; and 0.14 percent/percent for insurance. In general, we conclude that these societal elements are not highly sensitive to the possible impact of a Market Share Shift up to large cars, which might occur due to the availability of Title II information.

8.0 SCENARIOS

8.1 General

The purpose of scenarios in this study is to investigate "what if" questions and determine possible effects of alternative aspects of Title II implementation on a broad scale, rather than to seek precise solutions to specific prognostications of what "will" happen over the next 10 years (1976-1985) as a consequence of Title II. We make no suggestion that we have any prescient insight into the way the future will unfold. We do believe, however, that we can pose rational questions concerning interrelated events, and cast them in the context of, "What will be the impact of this event (or set of events) if Title II is implemented in this fashion?"

It is with these thoughts in mind that the remainder of this discussion of scenarios is presented.

8.2 The Broad Picture

Title II requires that the Secretary of Transportation determine and disseminate information on the following characteristics of passenger motor vehicles:

(1) Crashworthiness
(2) Damage Susceptibility
(3) Ease of Diagnosis and Repair

Title II information of this type received and acted upon by the buying public could lead to shifts in car buying patterns. In turn, because of the availability of Title II information, and/or changes in car buying attitudes, manufacturers may elect to make changes in cars to improve the Title II characteristics, thus making their products more attractive to the buying public.

In addition to Title II-related direct effects, such as those noted above, events of a larger national or global scale are also likely to occur and have major effects over the next ten years. For example, the following are possibilities that may occur:

- Significant increase in the price of gasoline, causing buyers to shift from purchase of Intermediate and Full Size cars to Compacts and Subcompacts.
- A substantial weight tax (annual or at time of purchase), which causes car buyers to prefer small cars.
- Gasoline rationing, which causes car buyers to prefer small cars.

The above are typical elements of scenarios. They have the (assumed) effect of causing car buyers to reject large cars which get low gasoline mileage, and turn to small cars that provide good gasoline economy. They are "global" or "national" elements of scenarios which may far overshadow some effects of implementing Title II.

8.3 Potential Title II Impacts

The anticipated effects of implementation of Title II involve the following:

- *Crashworthiness:* In general, heavy larger cars are more crashworthy than small light cars.[*] Therefore, it is assumed that the informed Title II buyer will try to buy a larger, more crashworthy car.
- *Damage Susceptibility:* On the basis of collision claim payments[†] Subcompacts are most prone to damage, and Full Size cars receive the least damage in an accident. However, this general trend is reversed when Compact and Intermediate cars are compared; the average annual crash repair cost for Intermediates tends to be about 4 percent higher than that of Compacts. The net impact of Title II information on damage susceptibility should be a trend from Subcompacts to Compacts and Intermediates to Full Size or Compacts.[‡]
- *Maintenance and Repair:* The difference in maintenance and repair varies by only a few percent in the first few years of a car's life. But over a 10-year lifetime, Compacts are cheapest (about $184/year); Subcompacts are 1.25 percent higher ($186/year); Intermediates are 8.6 percent higher ($200/year); and Full Size cars are 18.4 percent higher ($218/year). Largest expenses occur in the sixth and, for large cars, also the eighth years of the car's life: expenses in the sixth year tend to be about four times those in the first year and twice those in the second year. Therefore, the general impact of Title II information on maintenance and repair might be negligible for buyers

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[*] P.L. Milic, *An Analysis of Accidents in New York State by Make of Vehicle*, New York State Department of Motor Vehicles, June 1972.

[†] Highway Loss Data Institute. *Automobile Insurance Losses, Collision Coverages, Variations by Make and Series 1973 Model*, 1974.

[‡] The conclusions may not necessarily be correct, because an older study covering collision and liability claims (thereby being more representative) found that average repair cost for Compacts was 3 percent higher than for Subcompacts, and average repair costs for Full Size and Intermediates were equal, and 2.5 percent higher than for Compacts. See *Crash Damage to Automobiles, An Insurance Research Study*, October 1972 (Allstate Insurance Company, Kemper Insurance Companies, Liberty Mutual Insurance Companies and State Farm Mutual Insurance Company).

who do not keep new cars more than three or four years. For those who keep a car for many years, Title II information might cause them to prefer smaller cars. More likely, however, is the impact of switching to a different make within a car class, that has a better (or, the best) maintenance and repair record.

In summary, Title II information on *Crashworthiness* will probably cause buyers to shift to larger cars. Information on *Damage Susceptibility* will probably cause buyers to shift to Compacts or Full Size cars. Information on *Maintenance and Repair* will cause buyers to shift to smaller cars, particularly Compacts.

Of the three passenger car characteristics for which Title II information is to be developed, it is judged that information on crashworthiness will be the most important. This judgment is supported by the results of the Private Consumer Study (see Section 4 and Appendix B). It may then be concluded that the net impact of Title II will be to:

- Induce buyers to buy larger cars with better crashworthiness and less damage susceptibility; and/or
- Induce manufacturers to improve the crashworthiness and/or reduce the damage susceptibility of smaller cars.

The first item tends to run counter to the effect on car sales anticipated from global and national incidents.

8.4 Other Aspects of Scenarios

In the discussion above, we have outlined the salient elements of the Title II and extra-Title II effects that may establish the nature and bounds of scenarios of interest to this study. That is, the net effect of Title II information will influence the public to buy larger cars. Conversely, the increasing effects of increased cost of energy (and inflation) appears to influence the public to buy smaller cars. In general, the manufacturers are expected to devote their efforts towards extolling the virtues of large cars, since larger profits can be thus accrued. However, if taxes or regulations effectively limit car size, manufacturers may be expected to stress both economy of performance and to improve crashworthiness of small cars to improve their competitive edge within a lower and narrower weight range.

It follows that for the above conflicting reasons, our scenarios should encompass:

- Market Share Shifts Up to larger cars.*
- Market Share Shifts Down to smaller cars.
- Market Share Shifts that occur abruptly, due to
  - Sudden increases in the cost of gasoline
  - Suddenly imposed gasoline rationing
  - Suddenly imposed taxes on new car weight
  - Sudden exposure to widespread Title II information
- Market Share Shifts that occur gradually over several years, due to gradual changes in gasoline cost, etc., and gradually increasing availability of Title II information.
- Reductions in projected new car sales, due to inflation, increased cost of energy, and a generally lower level of affluence throughout the country.
- Decreases in weight of cars, to improve gasoline mileage.
- Increases in weight of cars, to improve crashworthiness and/or reduce damage susceptibility.
- Increases in risk factor†, due to decreased weight of cars.
- Decreases in risk factor, due to implementation of new safety features, such as air bags, etc.

Combination of the above elements comprise the variables for the scenarios investigated in this study.

8.5 Potential Results from Scenarios

Once a scenario has been posited, our knowledge of the characteristics of the societal consequences models permits us to suggest what we expect the outcome to be. There are three societal consequences models:

- Accident Model
- New Car Sales Model
- Car Operations Model

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*Market Share Shift is defined as the sum of the share of the total market lost by some makes (or classes) of cars plus the share of the market gained by other makes of cars (or classes). That is, if Car A captures an additional 5 percent of the total market, and Cars B and C lose 2 and 3 percent, respectively, then the Market Share Shift is 10 percent. Throughout this report a Market Share Shift "up" means more larger cars are sold, and a Market Share Shift "down" means more smaller cars are sold. In all cases, we use our estimate of the Market Shares for all the registered "1975 & Before" cars as our base for comparison.

†Risk factor is defined to be the conditional probability of a fatal or serious injury (FOSI), given that a car has crashed.

The response of the models to the various inputs denoted in Section 8.4, above, are presented next.

Accident Model:

- Market Share Shifts. Any shift in Market Shares which results in a net increase in larger cars will result in an increase in FOSI averted. If the shift takes place gradually, rather than abruptly, the 10-year average value of FOSI averted will be less.

- Reduced New Car Sales. Reduction in the sale of new cars, for a given Market Share Shift, will reduce the number of FOSI averted, simply because there are fewer registered vehicles which can become involved in accidents. If the new cars have lowered risk factors (due to improved crashworthiness), then the percent of FOSI averted will decrease as new car sales decline because a smaller fraction of the total registered car population will be in new cars.

- Change in Car Weight. As the average weight of new registered cars declines, the FOSI averted increases, because the new cars are less aggressive, relative to the "1975 & Before" cars. Conversely, if the average weight of new registered cars increases, then there will be fewer FOSI averted.

- Change in Risk Factor. When the risk factor is reduced (by air bags, improved structure, etc.), there will be an increase in FOSI averted, because the new cars are more safe. The converse also holds. The Accident Model is more sensitive to changes in risk factor than any other parameter.

New Car Sales Model:

- Market Share Shifts. The only variable inputs to this model are market shares and new car sales. If the net result of a Market Share Shift is an increase in the number of larger cars sold, then all of the model outputs--revenue from sales, sales margin, value added, and employment--will increase. If the net shift is to small cars, the outputs will decrease.

  The rates at which change takes place as a function of Market Share Shift are small--all of the order of one percent or less change in an output variable (such as employment or value added) per percent change in Market Share Shift.

  In general, most of the characteristics in the New Car Sales Model used in this study are monotonic increasing functions of car weight; only one--consumer expenditures for options on cars--is nonmonotonic. (This occurs because the cost of many so-called options are included in the basic price of Full Size cars.) Two of the characteristics are nonlinear monotonic increasing functions of car weight: Consumer expenditures for basic cost of cars and dealers sales margins. These increase exponentially with increased car weight. The remainder of the characteristics--manufacturers and suppliers employment and value added--are assumed to be linear monotonic increasing functions of weight.

Car Operations Model:

- Market Share Shifts. As with the New Car Sales Model, the only variable inputs are market shares and new car sales. However, in this model, we consider:

  - Cost of gasoline consumption
  - Cost of crash repairs
  - Cost of maintenance and repair
  - Cost of insurance

  Data for each of the above are input to the model to allow investigation of 16 types of cars--4 in each of the four car classes. In general, there are different characteristics for each type of car, although characteristics within a class are quite comparable. Costs all tend to increase with car weight, so net Market Share Shifts to large cars increases the costs to society of gasoline consumption, maintenance and repair, and insurance, and net shifts to small cars tend to decrease these costs. The opposite can be said about crash repair: Shifting to small cars decreases the cost.

  The most sensitive of these four car operations characteristics is gasoline consumption. Crash repair has about one-fourth to one-third the sensitivity of gasoline consumption; maintenance and repair about one-fifth; and insurance about one-tenth the sensitivity of gasoline consumption.

  The rates at which change takes place are small; they are of the order of one-sixth of a percent increase in gasoline consumption for each percent increase in Market Share Shift to larger cars. The other three characteristics have commensurately smaller changes as noted above.

8.6 Extreme Scenarios, to Provide Solution Bounds

The first questions that come to mind concerning scenarios might be:

- What if everyone buys large cars because they want a safer car?
- What if everyone buys small cars because of gasoline cost and/or shortage?

The first question might be called the *"Maximum Effect of Title II;"* the second might be considered the *"Maximum Impact of the Energy Crunch."* In the course of looking at these extremes, we would want to consider not only what might be the impact of a complete Market Share Shift to Full Size or Subcompact cars, but also what the impact would be if the shift were to Intermediate and Compact cars. The results of investigation of these four extreme scenarios are shown in Table 8-1. In each case, we start with initial market shares of 20%, 20%, 40%, and 20% for "1975 & Before" Subcompact, Compact, Intermediate, and Full Size passenger cars. We assume that all new car buyers switch to one

preferred car class in 1976, and continue that buying practice for 10 years (1976-1985). During that time a total of 145.2 million cars are assumed to be sold, ranging from 9.8 million in 1976 to 15.6 million in 1985. (These figures are based on Department of Commerce forecasts*.) The data in Table 8-1 are the percent changes which take place in the 10-year averages of the parameters relative to what would have occurred had the public continued to buy (the same number of cars) with the Market Shares for the "1975 & Before" cars.

Table 8-1 illustrates extreme cases of Market Share Shifts. It also illustrates some of the subtle (essentially hidden) characteristics of the models themselves. *It is emphasized that results such as those shown in Table 8-1 should not be interpreted literally.* Rather, we should use such results in a comparative role, to indicate trends and rates of change. This caveat is important, and will be repeated from time to time. We make no suggestion that we have managed to accurately reflect total reality in our models. In fact, we know we have not. We merely proffer them as approximations to reality that are only as good as the model frameworks chosen, and the coefficients and data we have been able to extract from the literature and/or synthesis.

From the Accident Model results in Table 8-1, we see that our expectations (that shifts to small cars cause more fatal or serious injuries, and shifting to large cars averts FOSI) are borne out. Of importance to note is that our Accident Model indicates that Market Share Shifts alone can change FOSI Averted by, at most, about -14% or +15%. Changes outside these bounds would have to be accomplished by other changes in weight and/or risk factors.

The data in Table 8-1 for the New Car Sales Model illustrates several important points. First, a shift to all Subcompact cars appears to be critical to the economic indicators shown. This has been exacerbated somewhat by the model itself, in which we assume (based on empirical evidence†) that only half of the Subcompacts and 90 percent of the Compacts are produced within the

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*U.S. Department of Commerce, *U.S. Industrial Outlook, 1975, with Projections to 1980*, August 1974.

†*The Wall Street Journal*, Sales of Imported Automobiles tables, various issues throughout 1974.

TABLE 8-1

SOCIETAL CONSEQUENCES OF ABRUPT SHIFTS TO SINGLE CAR CLASSES

Model	Parameter	Change (10-Year Average in Percent)			
		Shift to Subcompact	Shift to Compact	Shift to Intermediate	Shift to Full Size
Accident Model	• Fatal or Serious Injuries Averted	- 13.8	- 10.61	+ 6.67	+ 14.67
New Car Sales Model	Consumer Expenditure				
	• Basic Cost	- 22.7	- 12.9	- 1.4	+ 38.4
	• Options Cost	- 43.7	- 9.2	+ 44.2	- 35.4
	Dealers				
	• Employment	0	0	0	0
	• Sales Margin	- 42.6	- 21.9	+ 6.4	+ 51.7
	Manufacturers				
	• Employment	- 43.2	+ 2.3	+ 13.6	+ 13.6
	• Value Added	- 57.3	- 11.5	+ 15.6	+ 37.5
	Steel				
	• Employment	- 58.2	- 5.9	+ 17.1	+ 29.7
	• Value Added	- 69.3	- 12.1	+ 19.3	+ 42.8
	Rubber				
	• Employment	- 51.6	- 1.6	+ 15.1	+ 23.0
	• Value Added	- 60.8	- 6.9	+ 17.4	+ 33.0
	Aluminum				
	• Employment	- 47.9	- 1.1	+ 14.4	+ 20.2
	• Value Added	- 54.9	- 4.3	+ 16.4	+ 20.4
	Plastics				
	• Employment	- 66.7	- 10.9	+ 19.2	+ 39.3
	• Value Added	- 87.1	- 22.1	+ 23.9	+ 61.4
	Paint				
	• Employment	- 51.4	- 1.5	+ 14.9	+ 23.1
	• Value Added	- 59.4	- 6.4	+ 17.0	+ 31.9
	Lead				
	• Employment	- 44.7	- 0.4	+ 15.0	+ 15.0
	• Value Added	- 47.3	+ 0.5	+ 14.7	+ 17.4
	Copper				
	• Employment	- 48.2	- 0.8	+ 14.2	+ 20.8
	• Value Added	- 55.1	- 3.8	+ 16.5	+ 26.0
	Glass				
	• Employment	- 46.3	+ 0.7	+ 14.0	+ 17.7
	• Value Added	- 49.6	- 1.1	+ 15.2	+ 20.4
Car Operations Model	• Gasoline Consumption Cost	- 28.4	- 12.4	+ 13.57	+ 13.64
	• Crash Repair Cost	+ 8.5	+ 3.5	+ 0.2	- 9.2
	• Maintenance & Repair Cost	- 3.2	- 3.9	+ 0.7	+ 5.8
	• Insurance Cost	- 2.2	- 0.8	+ 0.4	+ 2.3

U.S. The remainder are assumed to be foreign-made. There is little doubt that in reality, if there were a large swing to Subcompacts, a much larger fraction (possibly all) would be produced in the U.S., thus reducing by about one-half the amplitude of all manufacturers and suppliers characteristic results. (Note that consumer expenditures and dealers characteristics are assumed to be independent of the size of foreign car sales in the U.S.0

In general, we assume that dealers and manufacturers employment is independent of the type of car manufactured.* This explains the row of zeros for dealers employment. The fact that manufacturers employment changes is due to the assumption that only 50 percent of the Subcompacts and 90 percent of the Compacts sold in the U.S. are assumed manufactured in the U.S. So, as car sales shift to Intermediate and Full Size cars, the model indicates an increase in employment.

If consumers bought all of any type of car but Full Size, they would expend less on the basic cost than they would if the "1975 & Before" Market Shares were perpetuated to 1985. However, if the shift is to Intermediate cars, all other characteristics (except consumer expenditures for the basic car cost) would increase.

In the case of a total shift to Full Size cars, all economic indicators except consumer expenditurefor car options go up. In actuality, there would be no drop in the production of equipment termed "optional," because it is the practice of manufacturers to include more of so-called options in the basic price of Full Size cars.

The results of the Car Operations Model also appeal to our intuition. Gasoline consumption cost goes down by more than one-fourth if the switch is to Subcompacts, and up nearly 14 percent if the switch is to Intermediates or Full Size cars. A shift to larger, safer cars is apt to be a result of the availability of Title II information on crashworthiness and (to a lesser degree) crash repair. The model indicates that such a shift would cost society no mor than a 14 percent <u>increase</u> in gasoline consumption ($77 billion over 10 years, @ $0.50/gal) and a 9 percent <u>decrease</u> in crash repair (about $5 billion over

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*Private telephone conversations with United Auto Workers, General Motors Corporation and the Bureau of Labor Statistics.

10 years).* Maintenance and repair would increase about 6 percent (about $12 billion over 10 years), and insurance costs would increase slightly more than 2 percent (a little less than $4 billion over 10 years). This suggests that the net increase in cost to society for car operations, *assuming that all car buyers shift to Full Size cars,* would be at most about $90 billion over 10 years. This would result (according to the Accident Model) in about 15 percent of the FOSI being averted (i.e., a reduction in FOSI of about 900,000 over 10 years out of about 6.2 million FOSI that would occur during that time, assuming no shift in Market Shares).

In actuality, it is doubtful that Title II information would cause a shift to Full Size cars of more than about 5 or 10 percent of the total market. That is, instead of 20 percent of the registered passenger cars being Full Size, as is the case at present, the influence of Title II information might cause this to increase to 25 or 30%. Of course, the influence of the high cost and/or shortage of gasoline, or heavy taxes on large car weight, could greatly counteract the effect of Title II information. We believe it is clear that when the decision to purchase is made, it is basic and operational costs, not subtle or even dramatic differences in crashworthiness, that prevent most people from buying a larger, more luxurious car--which fortuitously may also be more crashworthy.

* * * * * *

In summary, the discussion above sets the stage for consideration of other, less extreme, scenarios. We have established bounds, *as produced by the models,* within which we can expect solutions to occur. Because our four scenarios (or, one scenario with four variations on the theme) were extreme, we may assume that many of the results to be expected from more realistic scenarios will be smaller by factors of possibly 5 or 10. This suggests that over the next 10 years the societal consequences of the availability of Title II information may be small, especially if considered in the context of events of a global or national character. Certainly, the impact of higher energy costs causing a trend toward

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*In reality, crash repair costs would not decrease this much (they might even increase), because there would be far more Full Size cars crashing into other Full Size cars than is presently the case. The models we are using do not incorporate this level of sophistication, which is not necessary as long as Market Share Shifts are relatively small (i.e., ± 20 or 30 percent at most).

smaller cars counters the expected trend of the public to buy larger, safer cars, once comparative Title II information on crashworthiness becomes available.

A trend toward small cars will increase FOSI and depress the economy, because less will be spent for all aspects of cars except crash repair. A shift toward large cars would avert FOSI and cost the buying public more.

The scenarios discussed next are designed to give an approximate idea of trends under conditions that are possibly somewhat more realistic. At least we consider them to be more plausible.

9.0 RESULTS FOR SELECTED SCENARIOS

9.1 Scenarios Selected

To illustrate the potential societal consequences of the availability of Title II information and other possible major influences, four scenarios have been investigated in detail for this report. They are highlighted in Table 9-1.

TABLE 9-1

SELECTED SCENARIOS INVESTIGATED

Scenario	Market Share Shift
#1	20% up to large cars
#2	20% down to small cars
#3	30% down in 1976 20% down in 1977 10% down in 1978 and later
#4	7.26% up to large cars, based on the Private Consumer Study

These scenarios provide a framework for comparison. Scenario #1 is a typical example of what might occur if Title II information were disseminated, *and no other events influenced buying habits.*

Scenario #2 might occur if gasoline becomes more expensive and/or becomes scarce and/or a large weight tax is levied against automobiles.

We have investigated Scenarios #1 and #2 under two conditions. First, we assumed that the Market Share Shift takes place abruptly in 1976 and continues throughout the 10 years. Second, we have assumed that the shift occurs gradually in a linear fashion, over four years (1976-1979), and then continues through 1985.

In Scenario #3, an intermediate case is investigated. We assume that the fuel situation creates a 30 percent Market Share Shift to small cars in 1976, but as Title II information becomes more available, the buying public shifts back towards large cars. However, the fuel crisis continues, resulting in an overall 10 percent Market Share Shift* down to small cars which occurs in 1978 and continues through 1985.

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*There is a 10 percent Market Share Shift down in years 1978-1985. The weighted average Market Share Shift for the ten-year period is 12.41 percent down to small cars, using the projected new car sales for each year, as discussed in Appendix E.

Scenario #4 is based on data (Burke) developed in the Private Consumer Study, which provides information on four cars within each of the four car classes. We assume the same initial Market Shares by car class as used in Scenarios #1, #2, and #3.* The Burke data are used to distribute Market Shares within each car class, and to determine how the Market Share for each car will change, under the assumption of the availability of Title II information in 1976. The new Market Shares are assumed to hold constant throughout 1976-1985.

9.2 Impact on Fatal or Serious Injuries

Table 9-2 shows the changes in Risk Factor and Weight that were investigated for all four scenarios. For Scenarios #1 and #2, these changes were made both abruptly (in 1976) and gradually (1976-1979). The changes were made only gradually for Scenarios #3 and #4.

TABLE 9-2

CHANGES IN RISK FACTORS AND WEIGHTS

Car Class	Risk Factor			Weight (pounds)		
	1975 & Before	1976, or 1976-1979	Reduction	1975 & Before	1976, or 1976-1979	Reduction
Subcompact	0.075	0.045	0.030	2200	2000	200
Compact	0.065	0.035	0.030	3200	2900	300
Intermediate	0.045	0.020	0.025	3800	3400	400
Full Size	0.035	0.015	*0.020*	4400	3900	*500*

*The "1975 & Before" Market Shares are:

Subcompacts:	20%
Compacts:	20%
Intermediates:	40%
Full Size:	20%

The combinations of conditions investigated with the Accident Model and the resulting 10-year average values of Fatal or Serious Injuries averted are shown in Table 9-3. The purpose of this investigation was to show the following:

- Impact of improvements in crashworthiness (reduction in Risk Factor) which might result from the use of air bag restraints;
- Impact of decreases in Weight, which might result from an effort on the part of manufacturers to improve gasoline efficiency;
- Impact of Market Share Shifts up to large cars as a consequence of Title II information on crashworthiness;
- Impact of Market Share Shifts down to small cars as a consequence of high gasoline prices and/or a shortage of gas and/or a tax on cars by weight;
- Impact of Market Share Shifts down to small cars, then gradually back up to large cars, leaving a net shift down to small cars; and
- Impact of Market Share shifts similar to those determined in the Private Consumer Study (see Section 4.2 and Appendix B), which involves all 16 cars.

The results of this Accident Model investigation are shown graphically in Figure 9-1. As was shown in Section 5, with no other changes taking place, abrupt Market Share Shifts to larger, safer cars result in an increase of about 0.12 percent FOSI Averted/percent Market Share Shift up to large cars, or an increase of about the same amount (slightly less) in additional FOSI incurred if the Market Share Shift is the opposite direction to small cars. If the Market Share Shifts take place gradually, the above rates are reduced to 0.092 and 0.090, respectively (i.e., a reduction in the rates of about 25 percent).

When the Risk Factors are reduced, as would be the case with air bag restraints, the 10-year average in FOSI Averted is in the range of 25 percent to 28 percent if the change takes place abruptly, and 19 percent to 22 percent if the change takes place gradually over 1976-1979. It is important to keep in mind that the reductions in Risk Factor average about 50 percent and, hence, it is not unusual to find at the end of 10 years (1985) that the annual FOSI Averted is also in the neighborhood of 50 percent. (And as noted elsewhere, the 10-year average FOSI Averted is about one-half of the FOSI Averted in the 10th year, in this model.)

Once risk has been reduced as indicated, the rate of increase of FOSI Averted becomes about 0.090 percent/percent Market Share Shift up for the abrupt change case and about 0.07 percent/percent Market Share Shift up for gradual change. That is, the rates diminish (by a little less than 25 percent) as crashworthiness improves.

TABLE 9-3

ACCIDENT MODEL CONDITIONS AND RESULTS FOR FOUR SCENARIOS

Scenario	Conditions				FOSI Averted [10-year Average] (%)
	Market Share Shift	Type of Mkt. Sh. Shift	Decrease in Risk Factor	Decrease in Weight	
1	20% Up	Abrupt[1]	0	0	+ 2.36
1	20% Up	Gradual[2]	0	0	+ 1.84
2	20% Down	Abrupt	0	0	- 2.30
2	20% Down	Gradual	0	0	- 1.80
3	12.4% Down	Down-up	0	0	- 2.61
4	7.26% Up	Abrupt	0	0	0.86
1	20% Up	Abrupt	Abrupt	0	28.63
1	20% Up	Gradual	Gradual	0	22.55
2	20% Down	Abrupt	Abrupt	0	25.02
2	20% Down	Gradual	Gradual	0	19.64
3	12.4% Down	Down-up	Gradual	0	18.87
4	7.26% Up	Abrupt	Gradual	0	21.80
1	20% Up	Abrupt	Abrupt	Abrupt	29.96
1	20% Up	Gradual	Gradual	Gradual	23.65
2	20% Down	Abrupt	Abrupt	Abrupt	26.32
2	20% Down	Gradual	Gradual	Gradual	20.71
3	12.4% Down	Down-up	Gradual	Gradual	19.95
4	7.26% Up	Abrupt	Gradual	Gradual	22.90

Notes: 1. Abrupt changes take place in 1976 and remain the same throughout 1976-1985.

2. Gradual changes occur linearly over four years (1976-1979), then remain the same throughout 1979-1985.

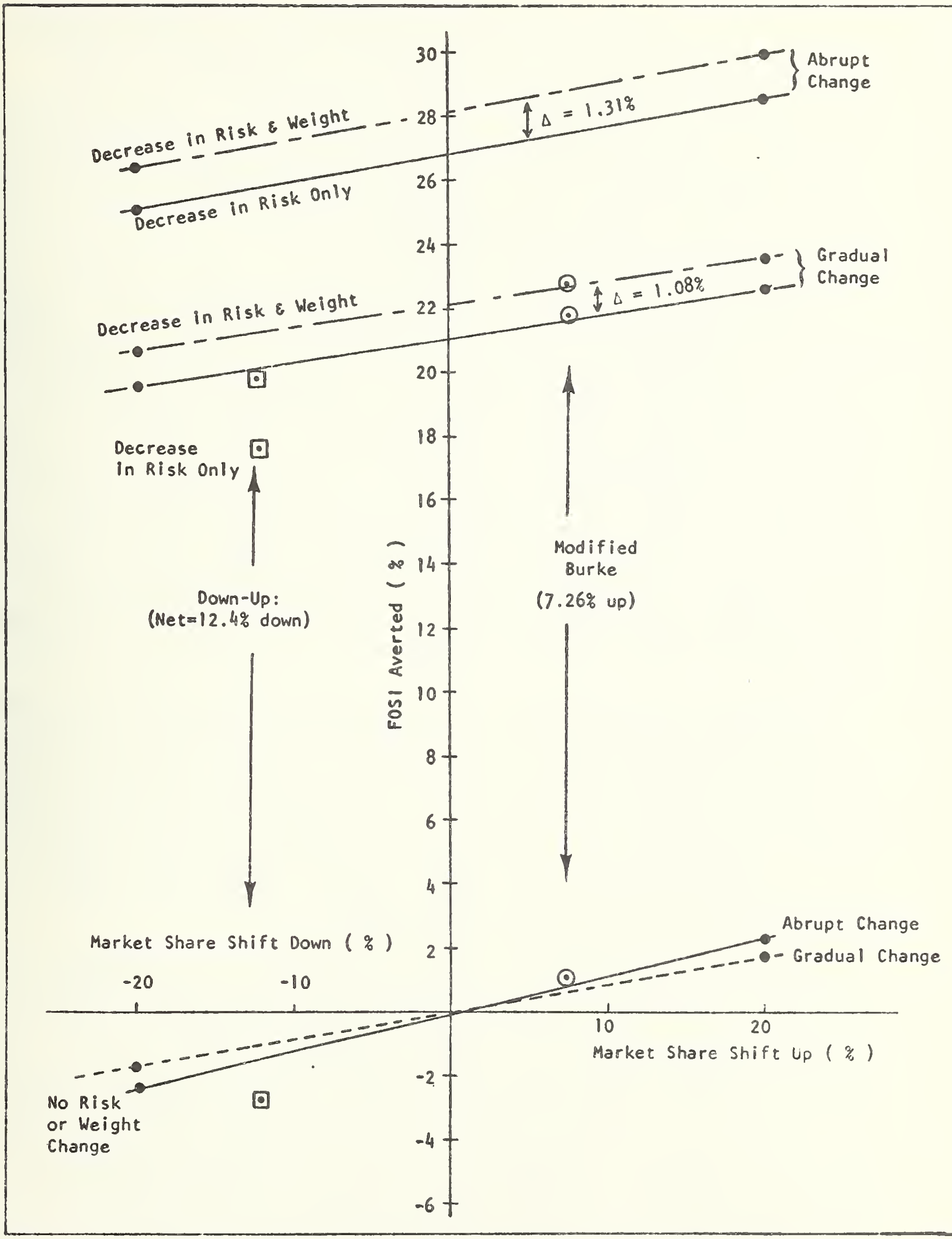

Figure 9-1. Comparison of fatal or serious injury (FOSI) averted for four scenarios.

When Weight reductions are added to improvements in crashworthiness, there is further improvement in FOSI Averted, but only about 1 percent (incrementally), as can be readily seen from Figure 9-1. The (unweighted) average weight change is 300 lb which implies that the rate of improvement is percent FOSI Averted per 100 lb reduction in the average weight of cars is about 0.44 if the change occurs abruptly in 1976, or about 0.036 if the change takes place gradually over 1976-1979.

In Scenario #3, the buying public shifts significantly to small cars in 1976 (30 percent Market Share Shift down), and then moves back somewhat to large cars in 1977 and 1978, due to availability of Title II information, and then stays at the 10 percent Market Share Shift down through 1985. Figure 9-1 and the data in Table 9-3 show that for this Scenario, the 10-year average of percent FOSI Averted will be reduced by about 1 percent, incrementally. Even so, with the Risk Factor and Weight reductions, the FOSI Averted will be about 20 percent (10-year average), which is essentially the same as what would happen, if the Market Share Shifts took place gradually over a four-year period, rather than following a "down-back up" pattern.

If changes take place among the four classes as determined from the Private Consumer Study (Burke data), then the results will closely parallel what happens if Market Share Shift changes take place gradually, as can be seen in Figure 9-1. (In Scenario #4 it is assumed that the Risk Factor and Weight changes take place gradually over 1976-1979, but the Market Share Shift of 7.26 percent up to large cars is assumed to take place abruptly in 1976 and continue through 1985.)

While it is not possible to explore in detail all the possible scenarios of what could happen in the 10-year period (1976-1985) when Title II information will be having its impact on public attitudes toward car purchases, we believe that these four scenarios, and the parametric changes that have been investigated, serve to give the reader an adequate appreciation for the trends and magnitudes of Fatal or Serious Injuries that may be averted (or additional incurred) as a consequence of the availability of Title II information or other events which may cause the public to change its buying habits and/or influence car manufacturers to make new cars more crashworthy and/or lighter. Additional detail is found in Section 5 and Appendix D of this report.

9.3 Societal Consequences for Four Scenarios

A summary of societal consequences for the four scenarios, assuming abrupt shifts of Market Shares in 1976, is shown in Table 9-4. For Fatal or Serious Injuries, we have assumed that both Risk Factor and Weight have been reduced as discussed above. This results in conditions which indicate the 10-year average in percent FOSI Averted may range between 23 percent to 30 percent. As can be seen from Figure 9-1, this is primarily dependent on the degree of change that can be made in passenger car crashworthiness. To a much lesser extent (i.e., by a factor of about 1/25), it also depends on Market Share Shifts and equally in reductions in Weight.

The societal consequences of new car sales are dependent on Market Share Shifts. If the buying public switches to large cars for more crashworthiness (Scenarios #1 and #4), all sectors of the passenger car industry will enjoy the impact of sales of more expensive cars. That is, the public will be paying more for more crashworthiness. However, in all cases, the impact on the societal elements is only a fraction of a percent increase for every one percent increase in Market Share Shift to large cars.

Should the public shift to the purchase of small cars because of the high cost or shortage of gasoline, or because of a weight tax on new cars, then the new car sales societal impacts would be negative "mirror images" of the shift to large cars, as illustrated by comparing results for Scenarios #1 and #2 in Table 9-4. Again, these effects all occur at (negative) rates of less than one percent per percent increase in Market Share Shifts to small cars. This means, of course, that dealers, manufacturers, and suppliers would all gross less money annually and employ fewer workers than would be the case if buying patterns were to continue for the next 10 years without change. In part, we may be seeing some of the impact of the shift to small cars in the 1975 model year market. However, the overall reduction in total cars sold is so overwhelmingly larger, that it may be difficult (if not impossible) for later researchers to assess the impact of a small shift to small cars in 1975, if it occurs.

It should be noted that the percentage changes in employment and value added for industrial suppliers for car manufacturers refers only to a percentage change in that segment of the entire industry (such as steel) which

TABLE 9-4

SOCIETAL CONSEQUENCES FOR FOUR SCENARIOS

Model	Parameter	Change (10-Year Average in Percent)			
		Scenario #1	Scenario #2	Scenario #3	Scenario #4
Accident Model	• Fatal or Serious Injuries Averted	29.96	26.32	19.95	22.90
New Car Sales Model	Consumer Expenditure				
	• Basic Cost	3.6	- 3.6	- 4.0	1.06
	• Options Cost	3.1	- 3.1	- 3.1	0.17
	Dealers				
	• Employment	0	0	0	0
	• Sales Margin	6.1	- 6.1	- 6.7	2.9
	Manufacturers				
	• Employment	3.4	- 3.4	- 3.8	1.8
	• Value Added	6.1	- 6.1	- 6.7	2.9
	Steel				
	• Employment	5.5	- 5.5	- 6.1	2.8
	• Value Added	7.2	- 7.2	- 7.9	3.5
	Rubber				
	• Employment	4.6	- 4.6	- 5.0	2.4
	• Value Added	5.9	- 5.9	- 6.5	2.9
	Aluminum				
	• Employment	4.2	- 4.2	- 4.6	2.2
	• Value Added	5.1	- 5.1	- 5.6	2.6
	Plastics				
	• Employment	6.8	- 6.8	- 7.4	3.3
	• Value Added	9.7	- 9.7	-10.6	4.6
	Paint				
	• Employment	4.6	- 4.6	- 5.0	2.4
	• Value Added	5.7	- 5.7	- 6.3	2.9
	Lead				
	• Employment	3.8	- 3.8	- 4.1	1.9
	• Value Added	3.9	- 3.9	- 4.3	2.1
	Copper				
	• Employment	4.2	- 4.2	- 4.6	2.2
	• Value Added	5.1	- 5.1	- 5.6	2.6
	Glass				
	• Employment	3.9	- 3.9	- 4.2	2.0
	• Value Added	4.3	- 4.3	- 4.7	2.2
Car Operations Model	• Gasoline Consumption Cost	3.40	- 3.40	- 3.82	+ 1.33
	• Crash Repair Cost	- 0.90	+ 0.90	+ 1.07	- 0.57
	• Maintenance & Repair Cost	0.68	- 0.68	- 0.79	+ 0.24
	• Insurance Cost	0.28	- 0.28	- 0.32	+ 0.14

supplies the car manufacturing industry. Thus, a 5 percent change in employment of steel suppliers does not mean a 5 percent change in total employment in the steel industry.*

The car operations societal impacts are also shown in Table 9-4. Gasoline consumption will increase if the Market Share Shift is up to larger, safer cars, and it will decrease if the shift is down to small cars. On a percentage of change basis, this factor is the most sensitive of the four societal elements in the Car Operations Model. Yet, even this element varies only about 0.17 percent (10-year average) for each percent change in Market Shares Shift.

Table 9-4 indicates that crash repair costs will increase with a shift to small cars, and decrease with a shift to large cars. However, the model is not highly accurate in this regard, and a large shift to small cars and associated attenuation of older, large cars over the 10-year period might not result in the crash repair cost suggested, because there would be few large car-small car crashes and more small car-small car crashes. The resources available for this study did not permit the addition of refinements to accommodate such subtle effects.

In any event, the percentage changes (10-year average) in the cost of crash repair, routine maintenance and repair and insurance are all about or less than 1 percent for the conditions investigated in the four scenarios, indicating that the rates of change in these parameters' percentages are all equal to or less than about 0.05 percent change in the parameter per 1 percent change in Market Share Shift. In short, none of the car operations parameters are highly sensitive to small changes in Market Share Shift. For Major Market Share Shifts (i.e., 50 percent or more), a more sophisticated model would probably be justified.

If the Market Share Shifts discussed above were to take place gradually, over 1976-1969, the effects noted in Table 9-4 would all be reduced in magnitude by about 20 percent to 25 percent, further cushioning what in many instances appear to be relatively small impacts.

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*Only about 15% of steel employment serves the car manufacturers. Therefore, a 5% change in this fraction of employment implies a 0.75% change in total steel employment. See the discussion at the end of Section 6.6 for other suppliers to car manufacturers.

APPENDIX A

REFERENCES
AND
INFORMATION SOURCES

A-1. REFERENCES AND INFORMATION SOURCES

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APPENDIX B

PRIVATE CONSUMER STUDY

B. PRIVATE CONSUMER STUDY

To estimate the impact of Title II information on potential automobile buyers, a "laboratory" study involving licensed drivers was conducted. Participants were only informed that we wanted to find out what people think about and consider when buying a new car and were given "booklets" describing 16 hypothetical cars in a standardized format. They were also given a questionnaire, to be completed after perusal of the booklet. The questionnaire consisted of three parts: the <u>first</u> asked for expression of preference among the 16 cars; the <u>second</u> asked questions allowing inference on the individual's attitudes, especially with regard to cars and information acquisition on cars; the <u>third</u> asked specific questions with regard to the presentation of Title II information and some basic demographic data. The completed questionnaires were translated to punched cards and standard statistical analyses performed with them.

Since past experience with specific makes and models, and brand loyalty play a role in automobile purchases, it was initially considered using a selection of actual car models. However, since the Title II information available for presentation to the study subjects was highly uncertain, makes were not identified and the model names disguised to avoid potential legal complications. However, promotional material for the 16 cars was carefully studied, and names and verbal descriptions were developed which tried to follow the style of presentation and type of appeal used by the manufacturers as closely as possible. All information was presented in a standardized format, following in general the format used by one manufacturer for two-page descriptions of cars.

These descriptions contained a verbal "sales pitch," technical data, a description of standard and optional equipment, fuel economy information taken from EPA publications, and an evaluation from a hypothetical "Automobile Testing Institute." These followed the style of the automobile evaluation given in *Consumer Reports* and the content was also taken from that publication, shortened and rephrased.

One fifth of the subjects received only the information described above. The other four-fifths got in addition, Title II information: 90 percent of the participants received presentations; and the other 40 percent got numerical presentations. Within each of these groups one-half received "real" values and the other half were given "distorted" values.

"Real" values were the best estimates which we could make for Title II information; in the "distorted" values, certain cars were given much better values of Title II information than the "real" one. The numerical measure of Title II information for the 16 cars is shown in Table B-1.

TABLE B-1

TITLE II INFORMATION FOR 16 HYPOTHETICAL CARS
(Numbers in Parentheses are "Distorted" Information)

Car	Crashworthiness Percent Fatal or Serious Injury in a Crash	Crash Repair Cost ($ Per Crash)	Repair and Maintenance Cost ($ Per Year)	Insurance Discount (Percent)
Subcompact				
Bat	7.3	535	170 (135)	0
Alba	7.3	510	170	0
Chee-Sai	7.3 (6.3)	485	190	10
Mini	8.5	480 (400)	210	0
Compact				
Gnome	6.9	555	190	10
Beacon	5.0 (4.3)	510	185 (150)	30
Libra	6.5	470 (390)	240	20
Musketeer	6.2	530	215	10
Intermediate				
Machete	3.5 (3.0)	565	245	40
Aladdin	4.2	515	250	30
Oriole	5.0	520	195 (155)	30
Diadem	6.0	480 (390)	230	30
Full Size				
Ocelot	2.8 (2.2)	520	275	50
Condor	3.8	480 (400)	235 (190)	40
Hastings	3.5	560	250	40
Taurus	4.9	480	250	30

As a measure of crashworthiness, the percentage of fatal or serious injury in a crash was presented. Estimates were made on the basis of New York State and North Carolina studies.*

The average repair cost per accident was given as a measure for damage susceptibility. Average collision claim payment figures published by HLDI† were used as a basis. The HLDI figures included not only payments for repairs, but also payments for cars declared total losses. But they excluded losses below $80, the average deductible. Estimating that the total losses and the repair cost below $50 per crash amounted to approximately the same number of dollars, we used the HLDI figures without correction.

To measure ease of diagnosis and repair we used an estimate of the average repair and maintenance cost per year. As a basis for the figures, we used FHWA estimates of maintenance and repair cost by car class,‡ and made adjustments for each car, according to the frequency of repair reported by *Consumer Reports:*¶ average, below average, above average. Obviously, these figures are, at best, very crude approximations of reality.

A special problem arose with insurance cost. Current insurance premiums--collision, liability, and liability and no-fault-liability combinations--do not depend on crashworthiness, and only in certain cases (bumper discounts) on damage susceptibility. Considering that the U.S. Congress considered no-fault insurance when studying crashworthiness and repair cost, we assumed a hypothetical insurance premium, consisting of a combination of no-fault and collision insurance. On the basis of the

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*P. Milic, *An Analysis of Accidents in New York State by Make of Vehicle* State of New York, Department of Motor Vehicles, DOT-HS-800-735, June 1972.

B. J. Campbell, D. Reinfurt, *Relationship Between Driver Crash Injury and Passenger Car Weight.* Highway Safety Research Center, University of North Carolina, November 1973.

†Highway Loss Data Institute, *Automobile Insurance Losses, Collision Coverages, Variation by Make and Series, 1973 Models.*

‡L. L. Liston, C.L. Gauthier, *Cost of Operating an Automobile,* U. S. Department of Transportation, Federal Highway Administration, April 1972.

¶*Consumer Reports,* various issues.

crashworthiness and repair cost, we assumed a hypothetical insurance premium, consisting of a combination of no-fault and collision insurance. On the basis of the crashworthiness and crash damage repair cost data, hypothetical premiums were calculated, and for each car a "discount" from the basic premium presented, ranging from 0 to 50 percent.

Numerically, the "best estimates" were presented. Graphically, a range of uncertainty with which the actual values would be, was presented by bars.

A total of 280 subjects participated in the survey. All but 54 were U.S. Government employees. The 54 non-Federal participants were drawn uniformly from the six regions where the survey was conducted. All but seven of the Federal employees worked for EPA. Overall, the group was highly educated--22 percent had postgraduate college education--and had an above average income--11 percent had a family income of $30,000 or more. Thus, results from this survey are not necessarily representative for all new car buyers.

Initially, a series of various exploratory analyses were conducted to determine whether demographic characteristics were related to car choices. Education, marital status, accident experience and being a government employee or not showed no obvious relationship to car preferences, but age and income did.

A factor analysis was conducted to determine psychological characteristics of the sample. The following factors were identified:

a) Car attributes:
   1. Continuing dependability
   2. Performance in operation
   3. Investment aspects

b) Information sources:
   1. Reliance on formal or expert sources
   2. Use of easily available source
   3. Use of specialized magazines

c) Attitude statement:
   1. Being a car opinion leader
   2. Being a "family worrier"
   3. Being risk oriented.

These factors showed no direct correlation with the demographic factors discussed above. On the basis of these results, it was decided to use age, income, and the three car attribute factors in an analysis of the expressed car preferences.

First, however, a very preliminary assessment of changes in car preferences with Title II information was made. The simplest comparison is between the frequencies of the cars being the best single choice. The results are shown in Table B-2. Overall, it is surprising that the major shift is from intermediates to full size cars, but practically no change for subcompacts and compacts. Some changes for individual cars, however, are apparent. The preference for Chee-Sai increases with Title II information. Chee-Sai has the lowest injury risk among the subcompacts in "real" terms and an even lower one in the "distorted" case. The preference for Libra increases with Title II information; Libra has the lowest real and even lower distorted crash repair cost among compacts, but an average injury risk. There is no change for the Beacon, which has the lowest injury risk in that class. In the intermediate class, the preference for the Oriole increases; it has the lowest repair and maintenance costs, and even lower in the distorted case. The preference for Diadem drops drastically; it has the worst crashworthiness in its class, though the lowest crash repair cost. In the full size class, the preference for the Ocelot increases; it has the lowest injury risk, and even lower in the distorted case.

TABLE B-2

SINGLE CAR CHOICES, BURKE AND U.S. TESTING GROUPS COMBINED

Car Preferred	Control Group (%)	Group With "Real" Title II Information (%)	Group With "Distorted" Title II Information (%)
Subcompacts:			
Mini	4.7	4.3	3.1
Chee-Sai	4.7	10.4	5.5
Bat	4.7	2.6	2.3
Alba	3.1	1.7	0
	17.2	18.2	14.0
Compacts:			
Musketeer	17.2	9.7	18.0
Libra	4.7	9.7	10.9
Gnome	6.2	7.8	3.1
Beacon	3.1	3.5	1.6
	31.2	30.4	33.6
Intermediate:			
Oriole	1.6	5.2	5.5
Machete	12.5	7.8	14.1
Diadem	14.1	3.5	4.7
Aladdin	4.7	2.6	3.1
	32.8	19.1	27.3
Full Size:			
Taurus	4.7	1.7	4.7
Ocelot	9.4	15.7	11.7
Hastings	1.6	8.7	5.5
Condor	3.1	2.6	3.1
	18.8	31.3	25.0

However, the preference for the Hastings increases strongly. It has only an average crashworthiness, the highest crash repair cost, and average repair and maintenance cost. Overall, the shifts suggest that Title II information may have some effect, but a clear picture is not provided. This is not surprising, because each individual made only one selection and personal differences in this small sample might well have influenced it more than the Title II information.

The following analysis, therefore, was performed as a second step. In addition to selecting one preferred car, each respondent rated each of the 16 cars on a scale ranging from, "there was no chance that he would consider it, if he were buying a car immediately," to "he was sure or almost sure that he would select it." These responses were translated into a numerical value. Thus, for each of the 16 cars,280 ratings were obtained. For each of the cars,the rating of purchase probability was correlated with the presence of Title II information: 0 if not presented, 1 if "real" and 2 if "distorted" information was presented. The results are shown in Table B-3: for subcompacts, all but one correlation coefficients are negative, for sull size cars, all but two are positive. For compacts and intermediate cars, the pattern is mixed. Though only one of the correlation coefficients (0.16 for the Libra, the relevance of which is questionable because the corresponding value from the other sample is - 0.14) is significant, the overall pattern is strongly suggestive of an influence of Title II information: the preference for subcompacts decreases when Title II information is available, the preference for full size cars increases.

It is not surprising that no clearcut results were obtained with such crude comparisons. In such a small sample, it is quite likely that the groups receiving no Title II and the various kinds of Title II information may have by chance a different composition. Therefore, further analyses were performed to determine how age, income, the individual's preference for car attributes, Title II information, or the numerical values of Title II information, relative to those of other cars in the same class, might determine the purchase probability. The results showed that the other information played the determining role. Title II information had, if any only a very small effect. The situation changed, however, when interactions were considered. Thus, interaction between Title II information and other factors had sometimes the strongest influence.

TABLE B-3

CORRELATION COEFFICIENT BETWEEN PURCHASE PROBABILITY RATING AND TITLE II INFORMATION
(Negative: Purchase Probability Decreases if Title II Information is Present)

Car	Burke Sample	U.S. Testing Sample
Subcompact		
Mini	- 0.01	- 0.03
Chee-Sai	- 0.02	- 0.06
Bat	- 0.05	0.01
Alba	- 0.03	- 0.11
	- 0.01	- 0 06
Compact		
Musketeer	0.12	- 0.12
Libra	0.16	- 0.14
Gnome	0.11	- 0.05
Beacon	- 0.09	0.00
	0.15	- 0.10
Intermediate		
Oriole	- 0.03	0.01
Machete	- 0.01	0.05
Diadem	0.06	- 0.06
Aladdin	0.03	0.00
	0.00	0.02
Full Size		
Taurus	0.01	0.05
Ocelot	0.05	0.07
Hastings	- 0.06	0.13
Condor	0.02	- 0.04
	0.03	0.06

It was concluded that buyer preference for each of the 16 cars was best expressed in the context of this study by the following regression equation:

$$\text{Buyer Rating for Car } i = \left[a_i + b_i \times \begin{pmatrix}\text{Age}\\ \text{Index}\end{pmatrix} + c_i \times \begin{pmatrix}\text{Income}\\ \text{Index}\end{pmatrix} + d_i \times \begin{pmatrix}\text{Age} & \times & \text{Income}\\ \text{Index} & & \text{Index}\end{pmatrix}\right]$$

$$+ \left[e_i + f_i \times \begin{pmatrix}\text{Age}\\ \text{Index}\end{pmatrix} + g_i \times \begin{pmatrix}\text{Income}\\ \text{Index}\end{pmatrix} + h_i \times \begin{pmatrix}\text{Age} & \times & \text{Income}\\ \text{Index} & & \text{Index}\end{pmatrix}\right] \times [0 \text{ or } 1]$$

$$= [\text{Term A}] + [\text{Term B}] \times [0 \text{ or } 1]$$

Inclusion or exclusion of Term B depends on whether Title II information was provided ["1"], or was not given ["0"]. The Age Index varied from 1 to 6, and the Income Index varied from 1 to 8. The relationships of the indices and ages and incomes are given in Table B-4 below.

TABLE B-4

INDICES FOR AGE AND INCOME

Age		Income	
Index	Years	Index	Annual Income ($ thousands)
1	Less than 25	1	Less than 5
2	25 through 34	2	5 to 7.5
3	35 through 44	3	7.5 to 10
4	45 through 54	4	10 to 15
5	55 through 64	5	15 to 20
6	65 and older	6	20 to 25
		7	25 to 30
		8	30 and more

The coefficients a_i through h_i were determined by stepwise linear regression analysis. Only very few regression coefficients turned out to be significant by conventional criteria. Our main objective, however, was not to determine which regression coefficients were significant and which were not, but to make predictions of the preferences for age and income groups with or without Title II information. Therefore, from the various steps that one was selected which gave the lowest error of the predicted purchase probability. The corresponding regression coefficients, if not zero, are presented in Tables B-5 and B-6.

A shift from smaller to larger cars would indicate that consumers are willing to pay more for increased safety. A closer look at the cost of the cars selected (in the single-car choice situation) and the options chosen gives the results shown in Table B-7.

TABLE B-5

REGRESSION EQUATION COEFFICIENTS FOR BUYER PREFERENCES
(Burke Data; 151 Respondents)

Class	Hypothetical Car	Title II Information Not Provided				Title II Information Provided			
		Constant (a_i)	Age Coeff. (b_i)	Income Coeff. (c_i)	(Age) (Income) Product (d_i)	Constant (e_i)	Age Coeff. (f_i)	Income Coeff. (g_i)	(Age) (Income) Product (h_i)
Sub-Compact	1. Bat	1.42				0.23	-0.16		
	2. Alba	1.71							-0.02
	3. Chee-Sai	2.73	-0.28						-0.02
	4. Mini	2.12			-0.06				
Compact	5. Gnome	2.89	-0.42						
	6. Musketeer	4.26	-2.10	-0.40	0.35	0.58	0.41		-0.10
	7. Beacon	4.29	-1.02	-0.37	0.15			-0.01	-0.02
	8. Libra	2.74	-0.41			0.26			
Intermediate	9. Diadem	2.88	-0.36						
	10. Oriole	2.49	-0.38						
	11. Machete	2.73	-0.32						
	12. Aladdin	2.26			-0.04				
Full Size	13. Condor	1.43				-0.24	0.14		
	14. Hastings	1.31			0.03				
	15. Taurus	1.07					0.08		
	16. Ocelot	2.29	-0.38					-0.06	0.04

TABLE B-6

REGRESSION EQUATION COEFFICIENTS FOR BUYER PREFERENCES
(U. S. Testing Data; 129 Respondents)

Class	Hypothetical Car	Title II Information Not Provided				Title II Information Provided			
		Constant (a_i)	Age Coeff. (b_i)	Income Coeff. (c_i)	(Age) (Income) Product (d_i)	Constant (e_i)	Age Coeff. (f_i)	Income Coeff. (g_i)	(Age) (Income) Product (h_i)
Sub-Compact	1. Bat	1.61	0.48		-0.1		-0.26		0.05
	2. Alba	3.76		-0.43	0.02	-0.65	-0.09	0.14	
	3. Chee-Sai	2.54		-0.11					
	4. Mini	2.51		-0.14					
Compact	5. Gnome	2.73		-0.13			-0.04		
	6. Musketeer	2.73							
	7. Beacon	2.59		-0.16					-0.02
	8. Libra	2.79							-0.02
Intermediate	9. Diadem	2.70	0.13	-0.15					
	10. Oriole	2.19		-0.08					
	11. Machete	2.06				0.10			
	12. Aladdin	2.27		-0.05					
Full Size	13. Condor	1.44		0.09					
	14. Hastings	1.27	0.57	0.55	-0.12	0.60		-0.08	
	15. Taurus	0.34		0.30			0.35		-0.06
	16. Ocelot	-0.08		0.43		0.32			-0.05

TABLE B-7

EXPENDITURES FOR CARS AND OPTIONAL EQUIPMENT
WITH AND WITHOUT TITLE II INFORMATION

Sample and Information Provided	Expenditures for:		
	Car	Options	Total
Burke:			
No Title II	2920	860	3780
With Title II	2030	780	2740
U.S. Testing:			
No Title II	2980	1060	4040
With Title II	3210	880	4090

Though consumers intend to spend more for the basic car, when provided with Title II information, they compensate for this by reducing their expenditures for options. The total expenditures are nearly identical with and without Title II information.

The preceding analysis dealt with the overall impact of Title II information on car purchase preferences. It did not ask which part of Title II information had the strongest impact. On an overall basis, the shift from smaller to larger cars suggests that crashworthiness or insurance discount (which is heavily influenced by crashworthiness) determines the reaction. A closer look on a car-by-car basis did not suggest that an individual car's Title II ratings relative to other cars in that class have an influence. Neither did an exploratory regression analysis. Therefore, we had to rely on the participants' expression of what they considered important.

Immediately after having expressed their car preference, participants were asked to indicate which information they found most useful in their decision-making in a "write-in" manner. Table B-8 presents the most frequent types of responses (combining similar though differently phrased responses). The low frequency of such obvious factors as "price" and "size" may be explainable if the subjects had already settled for a price-range or size-class and compared these features only within each class. Of Title II information, "safety" and "repair and maintenance" rank about equal.

TABLE B-8

MOST FREQUENT "WRITE-IN" RESPONSES TO THE QUESTION:
"WHAT INFORMATION IN THE BOOKLETS WAS MOST HELPFUL TO YOU IN MAKING UP YOUR MIND ABOUT THESE CARS?"

Information On:	Group	
	Burke (%)*	U.S. Testing (%)*
• *Consumer Report* Type Information	59	47
• Gasoline Mileage	48	43
• Repair and Maintenance Cost	28	21
• Safety	25	26
• Standard or Optional Equipment or Features	20	24
• Price	19	22
• Size	16	9
• Comfort		16
• Handling	14	10
• Engine, Performance	10	12
• Insurance Cost	7	10

*Percent of all subjects given the kind of information.

This contradicts the results of presenting Title II information. Obviously, respondents ultimately weighed repair and maintenance cost less than crashworthiness. Otherwise there would not have been a clear shift from smaller to larger cars, which are more expensive to repair. Insurance cost ranks very low, and crash repair cost does not appear at all. This is understandable, because in many cases these costs are covered by collision insurance or paid for by another party's disability insurance.

Finally, the participants were asked several questions about the understandability of various ways of presenting Title II information. Different approaches to this question yielded consistent results which are summarized in Figure B-1, ranking the various alternatives in a categorical way (also, given below are the rankings on a quantitative scale of understandability).

BEST

Single Number

CRASHWORTHINESS
NUMBER OF FATAL OR SERIOUS INJURIES PER 100 ACCIDENTS
7.6
8.1
8.9
5.2
6.2
5.8

1.5

GOOD

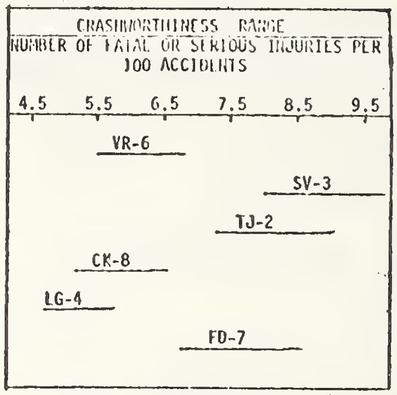
Range of Numbers

CRASHWORTHINESS RANGE
NUMBER OF FATAL OR SERIOUS INJURIES PER 100 ACCIDENTS
6.8 - 8.4
7.3 - 8.9
8.0 - 9.8
4.7 - 5.7
5.6 - 6.8
5.2 - 6.4

1.7

FAIR

Graphed Range



2.1

FAIR

Single Percent

CRASHWORTHINESS
NUMBER OF FATAL OR SERIOUS INJURIES PER 100 ACCIDENTS (% OF AVERAGE FOR CARS IN THIS CLASS)
125.2
95.8
89.6
137.6
117.5
80.4

2.2

Rank on a scale of "1" = Best, "5" = Worst

POOR

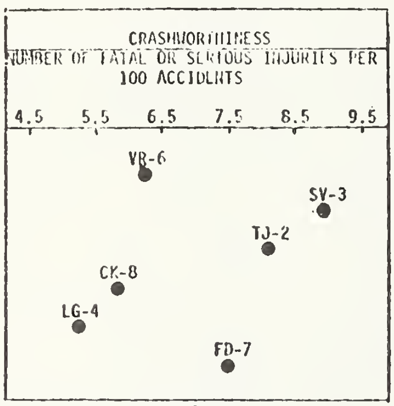
Single Rating

CRASHWORTHINESS RATING
RISK OF FATAL OR SERIOUS INJURY PER ACCIDENT
Better Than Average
Average
Better Than Average
Worse Than Average
Worse Than Average
Average

2.4

POOR

Graphed Single Value



2.5

POOR

Range for Rating

CRASHWORTHINESS RATING
RISK OF FATAL OR SERIOUS INJURY PER ACCIDENT
Better Than Average
Average
Better Than Average
Worse Than Average**
Worse Than Average
Average*

2.5

WORST

Range of Percents

CRASHWORTHINESS RANGE
NUMBER OF FATAL OR SERIOUS INJURIES PER 100 ACCIDENTS (% OF AVERAGE FOR CARS IN THIS CLASS)
112.8 - 137.6
86.6 - 105.1
80.4 - 98.9
[illegible]
[illegible]
[illegible]

2.8

Figure B-1. Understandability of ways of presenting Title II information.

APPENDIX C

DERIVATION OF NEW CAR DEMAND

C-1. INTRODUCTION

Using the table, "The Demography of Demand for New Cars" (Fabian Linden, "Profiling the New Car Market," The Conference Board Record, February 1969), the distribution of the sale of 1000 new cars by age and income group is obtained. (See Table C-1.) The work of projecting shifts in buying behavior has already been done with respect to the 1975 figures. Further, the 1975 income figures are expressed in constant 1967 dollars. Therefore, using the proper scaling factor, 1974 incomes can be expressed in 1967 dollars.

The problems involved in deriving the tables were:

(1) Converting summer 1974 income classes used by U.S. Testing to 1967 dollars, i.e., finding the proper deflator.

(2) Distributing the car sales properly over new income classes (because an exact match didn't exist).

TABLE C-1

THE DEMOGRAPHY OF DEMAND FOR NEW CARS
(Distribution per 1,000 new car purchases)

Household Income (1967 dollars)		Age of Household Head						
		Total	*Under 25*	*25-34*	*35-44*	*45-54*	*55-64*	*65 and over*
					1967			
Total		1,000.00	92.77	177.75	233.76	256.70	169.27	69.75
Under $3,000	1967	42.74	11.17	3.58	3.95	7.24	5.31	11.49
$ 3,000 - 5,000	1967	111.29	24.13	11.26	15.67	15.55	23.11	21.57
5,000 - 7,500	1967	223.37	27.19	61.63	45.57	44.06	24.71	20.21
7,500 - 10,000	1967	204.25	15.87	49.98	53.38	51.84	26.53	6.65
10,000 - 15,000	1967	266.35	12.59	40.13	79.49	77.50	51.30	5.34
15,000 and over	1967	152.00	1.82	11.17	35.70	60.51	38.31	4.49
					1975			
Total		1,000.00	135.16	206.62	192.10	221.01	169.35	75.76
Under $3,000	1975	30.32	10.57	2.39	1.85	4.07	3.52	7.92
$ 3,000 - 5,000	1975	81.56	21.53	7.66	7.79	8.45	15.88	20.25
5,000 - 7,500	1975	158.93	28.67	44.93	22.35	24.86	16.81	21.31
7,500 - 10,000	1975	223.63	41.53	63.29	40.93	39.28	30.52	8.03
10,000 - 15,000	1975	290.01	29.73	65.43	66.29	72.55	46.75	9.26
15,000 and over	1975	215.55	3.13	22.92	52.84	71.80	55.87	8.99

Source: U.S. Department of Commerce

C-2. RESOLUTION OF PROBLEM 1

After consulting statistical abstracts and Survey of Current Business, 6% per year was selected as a reasonable price deflator. This is less than the rise in the Consumer Price Index over that time period because some real growth in income is expected to have taken place.

C-3. RESOLUTION OF PROBLEM 2

In order to convert the six income classes in Linden's table to the eight income classes used by Burke and U.S. Testing, it was necessary to reduce the original data from a histogram to a smooth distribution and this was done for each age category. Next, the new income class limits, the 1974 incomes deflated to 1967 dollars, were superimposed on the graphs and the midpoints of the classes were taken to be the number of cars sold in that age group to that income class.

In the recomposed table the distribution still is for 1000 new cars sold. (See Table C-2.) The figures are least reliable in the extreme income categories because of the roughness of the methodology and lack of precise data in those areas.

TABLE C-2

NEW CAR SALES DISTRIBUTION BY AGE AND INCOME
(1000 Cars)

Annual Income ($1,000's)	(Age (years)) Less than 25	25 thru 34	35 thru 44	45 thru 54	55 thru 64	65 and Older	Total
Less than 5	11.55	3.08	1.54	3.08	2.31	7.7	29.26
5 to 7.5	19.25	18.94	9.24	6.16	12.32	17.71	83.62
7.5 to 10	26.95	38.50	19.25	19.25	12.32	17.71	133.98
10 to 15	26.95	50.05	40.81	42.35	27.72	6.16	194.04
15 to 20	19.25	40.04	46.20	54.67	37.73	6.16	204.05
20 to 25	12.32	26.95	40.04	54.67	40.81	6.93	181.72
25 to 30	4.62	16.94	32.34	40.81	32.34	6.93	133.98
30 or more	0	3.0	12.0	14.0	10.0	3.0	43.00
Total	120.89	197.5	20.142	234.99	175.55	72.3	1002.65

APPENDIX D

DATA BASE FOR THE ACCIDENT MODEL

D-1. NUMBER OF REGISTERED CARS - 1965 - 1985

Two variations of car registration are used--data sets of original estimates (A) and reduced estimates (B). In both cases, the car population up to 1975 is the same and based on actual registrations or car sales prior to 1975. For 1975 and later, estimates are obtained in the manner described below. Based on figures supplied by the Department of Commerce, the domestic production is projected to grow at a compound annual rate of 7.4 percent from 8.5 million in 1975 to 12.0 million in 1980. Further, it is assumed that growth beyond 1980 will be at the average rate defined by new car registration in 1973 and 1980. This amount is inflated by 15% to represent the number of imported cars registered in the U.S. Once the number of new cars of each model year is determined, it is necessary to distribute that number over actual calendar years. Since model years and calendar years do not coincide, and registration data are for July 1, only a portion of the model year total is registered in the first year. Also, a procedure had to be developed to "retire" vehicles from the population matrix as a function of age. The results of the procedure used are shown in Table D-1.

TABLE D-1

"SURVIVAL" PERCENTAGES OF PASSENGER CARS AS A FUNCTION OF VEHICLE AGE

Vehicle Age	% Survival
0	70 *
1	100
2	99.5
3	99.0
4	98.0
5	96.0
6	93.0
7	87.0
8	77.0
9	64.0
10	50.0
11	37.0

*Implies that only 70% of the new cars are sold by the end of the registration year.

The figures for vehicle survival were determined from tables of "U.S. Passenger Car Registrations by Year Model."* The details of the derivation of the survival curves are described in a CEM Final Report.†

These factors applied to the projected registrations of new cars in any one year give the vehicle population of that model year for the subsequent 10 calendar years.

The original estimate "A" of car registrations was constructed in this way, and the reduced car population matrix "B" was simply a 10 percent reduction in new car registrations for model years after 1975. The two sets of car registration populations are shown in Table D-2.

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*Motor Vehicle Manufacturers Association of the United States, Inc., *1973/74 Facts & Figures*, Detroit, annual.

†H. C. Joksch, *An Accident Trend Model*, The Center for the Environment and Man, Inc., Report 4148-510, 1974.

TABLE D-2

ACCIDENT MODEL CAR POPULATION

(a) Assumption "A" - Original Estimate

Model Year	Calendar Years										
	1975	1976	1977	1978	1969	1980	1981	1982	1983	1984	1985
1975≤	95.2	90.2	82.2	75.0	65.4	56.6	47.9	39.6	31.3	23.8	17.6
1976		7.4	10.6	10.6	10.5	10.4	10.2	9.9	9.2	8.2	6.8
1977			8.0	11.4	11.4	11.3	11.2	10.9	10.6	9.9	8.8
1978				8.5	12.2	12.2	12.1	12.0	11.7	11.3	10.6
1979					9.1	13.0	13.0	12.9	12.7	12.5	12.1
1980						9.7	13.8	13.8	13.7	13.5	13.2
1981							9.9	14.2	14.2	14.1	13.9
1982								10.2	14.5	14.5	14.4
1983									10.4	14.9	14.9
1984										10.6	15.2
1985											10.9
Totals	95.2	97.6	100.8	105.5	108.6	113.2	118.1	123.5	128.3	133.3	138.4

(b) Assumption "B" - 10% Reduction in Original Estimates

Model Year	Calendar Years										
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
1975≤	95.2	90.2	82.2	75.0	65.4	56.6	47.9	39.6	31.3	23.8	17.6
1976		6.7	9.5	9.5	9.4	9.4	9.2	8.9	8.3	7.4	6.1
1977			7.2	10.3	10.3	10.2	10.1	9.8	9.5	8.9	7.9
1978				7.6	11.0	11.0	10.9	10.8	10.5	10.2	9.5
1979					8.2	11.7	11.7	11.6	11.4	11.2	10.9
1980						8.7	12.4	12.4	12.3	12.1	11.9
1981							8.9	12.8	12.8	12.7	12.5
1982								9.2	13.0	13.0	13.0
1983									9.4	13.4	13.4
1984										9.7	13.7
1985											9.8
Totals	95.2	96.9	98.9	102.4	104.3	107.6	111.1	115.1	118.5	122.2	126.3

D-2. MARKET SHARES

This section describes the market share data used for the Accident Model and other Societal Consequences Models. Included are the actual data, except where it has been previously cited, the source of the data, and how the data were modified to explore the effect of market share shifts.

A. Burke Market Shares. Source: Burke Market Study (Section 4)

B. U.S. Testing Market Shares. Source: U.S. Testing Market Study (Section 4)

C. "Actual" Market Shares. Source: Monthly production figures for domestic cars and monthly sales of imported cars for March-July 1974.*

Derivation of Market Shares:

1975 and Before models: Market shares were derived by determining the number of cars produced or sold during the March to July 1974 period for each car class and allocating to each of the four car types in each class a market share in proportion to its production or sale during that period.

1976 and After models: Market shares were shifted from 1975 to 1976 in proportion to the average percentage shifts in the Burke and U.S. Testing data.

D. "Wuerdemann" Market Shares. Sets of Market Shares suggested by H. Wuerdemann are based on the assumption that the initial market shares are approximately 0.20, 0.25, 0.30, 0.25 and that there will be a shift to heavier, safer cars. The Market Shares are given in Table D-3.

TABLE D-3

WUERDEMANN MARKET SHARES (%)

Car Type	Model Year						
	1975	1976	1977	1978	1979	1980 →	1985
1	5.3	5.0	4.8	4.5	4.3	4.0 →	4.0
2	5.3	5.0	4.8	4.5	4.3	4.0	4.0
3	5.3	5.0	4.8	4.5	4.3	4.0	4.0
4	5.3	5.0	4.8	4.5	4.3	4.0	4.0
5	6.3	6.1	5.8	5.5	5.3	5.1 →	5.1
6	6.3	6.1	5.8	5.5	5.3	5.1	5.1
7	6.3	6.1	5.8	5.5	5.3	5.1	5.1
8	6.3	6.1	5.8	5.5	5.3	5.1	5.1
9	7.4	7.3	7.2	7.2	7.1	7.1 →	7.1
10	7.4	7.3	7.2	7.2	7.1	7.1	7.1
11	7.4	7.3	7.2	7.2	7.1	7.1	7.1
12	7.4	7.3	7.2	7.2	7.1	7.1	7.1
13	6.1	6.7	7.2	7.8	8.4	8.9 →	8.9
14	6.1	6.7	7.2	7.8	8.4	8.9	8.9
15	6.0	6.6	7.1	7.7	8.2	8.8 →	8.9
16	6.0	6.6	7.1	7.7	8.2	8.8	8.9

**Wall Street Journal*, Chicopee, Mass., March-July 1974.

E. "Joksch" Market Shares. Set of Market Shares suggested by H. Joksch are based on the fact that since the model had shown little sensitivity to the shifts in 16 car shares, it was decided to aggregate market shares into four classes of market shares.

The proposed market shares for Subcompact, Compact, Intermediate and Full Size classes are 0.16, 0.21, 0.42, 0.21. These are the estimates for the mix of 1975 and earlier models in the car population. The consequences of flattening those market shares as indicated by the Burke and U.S. Testing data was investigated.

F. Modified "Joksch" Market Shares. To facilitate interpretation of results, the Joksch market shares were simplified to the following shares: 0.20, 0.20, 0.40, 0.20. The greater bulk of the study centered around these initial market shares for the 1975 and earlier models. From this initial assumption, the market shares for 1976 and later models were varied in the following fashion:

1. Abrupt, Uniform Market Share Shifts
2. Gradual, Uniform Market Share Shifts
3. Abrupt, Non-Uniform Market Share Shifts
4. Gradual, Non-Uniform Market Share Shifts

Examples are given in Table D-4.

TABLE D-4

EXAMPLES OF MARKET SHARE SHIFTS

a. Abrupt, Uniform Market Share Shift Down 20% to Classes 1 and 2

Car Class	1975 and Earlier	1976 and Later	Shift
1	0.20	0.25	+ 0.05
2	0.20	0.25	+ 0.05
3	0.40	0.35	- 0.05
4	0.20	0.15	- 0.05
Total Shift for 4 Car Classes			0.20

b. Gradual, Uniform Market Share Shift Up 30% to Classes 3 and 4

Car Class	1975 & Earlier	1976	1977	1978	1979 → 1985	Shift
1	0.20	0.181	0.162	0.143	0.125 → 0.125	- 0.075
2	0.20	0.181	0.162	0.143	0.125 → 0.125	- 0.075
3	0.40	0.419	0.438	0.457	0.475 → 0.475	+ 0.075
4	0.20	0.219	0.238	0.257	0.275 → 0.275	+ 0.075
Total Shift for 4 Car Classes						0.30

c. Non-Uniform Gradual Market Share Shift Up 20% to Classes 1 and 2

Car Class	1975 & Earlier	1976	1977	1978 → 1985	Shift
1	0.20	0.30	0.275	0.25 → 0.25	+ 0.05
2	0.20	0.25	0.250	0.25 → 0.25	+ 0.05
3	0.40	0.35	0.35	0.35 → 0.35	- 0.05
4	0.20	0.10	0.125	0.15 → 0.15	- 0.05
Total Shift for 4 Car Classes					0.20

d. Non-Uniform Abrupt Market Share Shift Up 20% to Classes 1 and 2

Car Class	1975 and Earlier	1976 and Later	Shift
1	0.20	0.25	+ 0.05
2	0.20	0.25	+ 0.05
3	0.40	0.30	- 0.10
4	0.20	0.20	0
Total Shift for 4 Car Classes			0.20

G. Modified Wuerdemann Market Shares. The market shares proposed by H. Wuerdemann for 16 car types were collapsed for 4 car classes (0.20, 0.25, 0.30, 0.25). Analysis of market share shifts was done in a manner similar to that described above in (F).

H. Predominant Full Size Car Market Shares. Information contained in Automotive News, on November 4, 1974,* suggested that despite the trend away from standard size vehicles, this class would still probably represent the largest class of vehicles on the road. Therefore, the following market shares were proposed in order to examine the effects of this predominance: 0.20, 0.20, 0.20, 0.40. Market share shifts were made in a manner similar to that described above in (F).

I. "Modified Burke" Market Shares. The original Burke market shares were modified to reflect the 0.20, 0.20, 0.40, 0.20 market share scheme used in most analyses. In order to do this, the 16 car type market shares were allocated to the 4 car classes in proportion to their market shares and constrained by the 0.20, 0.20, 0.40, 0.20 market share proportions for the classes. They were then shifted by the same percentage as they were in the Burke study. The modified shares are given in Table D-5.

TABLE D-5

"MODIFIED" BURKE MARKET SHARES (%)

Car Class	1975 and Earlier	1976 and After
1	4.7	3.6
2	5.6	4.5
3	5.9	4.8
4	3.8	3.7
5	5.4	5.4
6	3.8	4.9
7	5.7	4.3
8	5.0	5.9
9	10.9	10.8
10	7.9	7.8
11	10.8	10.7
12	10.5	10.4
13	5.4	6.2
14	6.8	6.7
15	4.0	5.0
16	3.8	5.2

Automotive News, Detroit, November 4, 1974.

D-3. CAR WEIGHTS

Initial analysis began with weights for 16 car types. Upon discovering that the model was relatively insensitive to the individual weights within each class, most analyses were performed for four car classes. These weights are 2200, 3200, 3800, and 4400 lbs for the Subcompact, Compact, Intermediate and Full Size Car Classes. These weights are rounded averages of the best estimates of the curb weights of the 1974 cars in each car class. Curb weight is about 150 to 300 lbs heavier than shipping weight. Also, some effort was made to try to emphasize the more popular car weights in obtaining an average. Sources of shipping weights were obtained in Automotive News* and information on curb weights was contained in the two references cited below.†

The car weights were shifted over time in a manner similar to the shifts in market shares. That is, both abrupt and gradual shifts in weight, either up or down, were made.

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* *Automotive News*, 1973 Almanac, 37th Review and Reference Section, Detroit, April 30, 1973.

† B.J. Campbell and D. W. Reinfurt, *Relationship Between Driver Crash Injury and Passenger Car Weight*, Highway Safety Research Center, University of North Carolina, 1973.

B. J. Campbell, *Driver Injury in Automobile Accidents Involving Certain Car Models: An Update*, Highway Safety Research Center, 1974.

D-4. RISK FACTORS

Risk Factors are the probability of a fatal or serious injury, given that the car has been in a crash. The sources used to arrive at the risk factors are primarily Campbell and Reinfurt* and Milic's†. The conditional probability was plotted against vehicle weight and a smoothed curve yielded the risk factors for the average weights used in this study.

As with market shares and car weights, the data were consolidated from 16 to four car classes, the latter being 0.075, 0.065, 0.045, 0.035 for Subcompact, Compact, Intermediate and Full Size cars. The risk factors were modified to represent gradual and abrupt shifts up and down for 1976 and subsequent model years.

D-5. CRASH PROBABILITIES

The probability of a crash for any registered vehicle per year equals 0.10. In N.Y. State Accident Facts for 1974 , data indicated that of 6,455,005 registered passenger cars, a total of 613,248 had reported accidents in 1973. This percentage of 9.5% was rounded off to 10% for this study.

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*B.J. Campbell and D.W. Reinfurt, *Relationship Between Driver Crash Injury and Passenger Car Weight,* Highway Safety Research Center, North Carolina, 1973.

†P. L. Milic, *An Analysis of Accidents in New York State by Make of Vehicle,* New York State Department of Transportation, 1972.

APPENDIX E

DATA BASE FOR NEW CAR SALES MODEL

E-1. PERCENTAGE OF CARS PRODUCED IN THE U.S.

Data on passenger car production for 1971 and 1974 were taken from *Automotive News** and the *Wall Street Journal*†. Based on these sources, it was determined that approximately 16 percent of new car sales are attributable to foreign production. This figure can vary considerably from year to year and was rounded to 15 percent for this study.

Based on the assumption indicated by the Burke and U.S. Testing data that the new car market was approximately evenly divided among the four car classes, 50 percent of the subcompacts and 10 percent of the compacts were treated as foreign made and, therefore, not contributing to U.S. employment or production. Thus, the 15 percent figure is obtained as follows:

$$50\% \times 0.25 + 10\% \times 0.25 = 15\%$$

The 50 and 10 percent proportions are invariant in the model as presently constituted. Therefore, the percentage of imports changes with market shares proportioned differently among the four car classes. For instance, the 0.20, 0.20, 0.40, 0.20 distribution of market shares yields only 12 percent of cars as imports.

E-2. MARKET SHARES

Analyses were made with the New Car Sales Model using a subset of the market shares which were input to the Accident Model.

E-3. NEW CAR SALES

New car sales data were discussed in Section D-1 of Appendix D. There was no reason to include the reduced new car sales alternative, as all factors would simply be reduced by 10 percent. It should be noted that in the New Car Sales Model only new car sales and <u>not</u> the entire automobile population are considered.

**Automotive News*, 1973 Almanac, 37th Review and Reference Section, April 30, 1973, Detroit.

†*Wall Street Journal*, March-July 1974, Chicopee, Mass.

E-4. COEFFICIENTS FOR THE 22 SOCIETAL ELEMENTS

The coefficients for the 22 societal elements evaluated in the New Car Sales Model are given in Table E-1.

TABLE E-1

COEFFICIENTS FOR 22 SOCIETAL ELEMENTS

NO	SOCIETAL ELEMENT	COEFFICIENT FOR INDICATED MARKET CLASS				UNITS PER CAR PRODUCED
		SUBCOMPACT	COMPACT	INTERMEDIATE	FULLSIZE	
1	CONSUMER EXPENDITURE BASIC COST	2244.00000	2526.00000	2360.00000	4016.00000	(DOLLARS)
2	CONSUMER EXPENDITURE OPTION COST	285.00000	460.00000	730.00000	327.00000	(DOLLARS)
3	DEALERS EMPLOYMENT	0.01760	0.01760	0.01760	0.01760	(EMPLOYEES)
4	DEALERS SALES MARGIN	329.00000	448.00000	610.00000	870.00000	(DOLLARS)
5	MANUFACTURING EMPLOYMENT	0.08500	0.08500	0.08500	0.08500	(EMPLOYEES)
6	MANUFACTURING VALUE ADDED	674.00000	776.00000	912.00000	1085.00000	(DOLLARS)
7	STEEL SUPPLIERS EMPLOYMENT	0.02000	0.02500	0.02800	0.03100	(EMPLOYEES)
8	STEEL SUPPLIERS VALUE ADDED	160.89999	255.59999	312.39990	373.89990	(DOLLARS)
9	RUBBER SUPPLIERS EMPLOYMENT	0.00350	0.00960	0.01010	0.01080	(EMPLOYEES)
10	RUBBER SUPPLIERS VALUE ADDED	60.70000	80.12999	90.90999	103.03000	(DOLLARS)
11	ALUMINUM SUPPLIERS EMPLOYMENT	0.00163	0.00172	0.00179	0.00188	(EMPLOYEES)
12	ALUMINUM SUPPLIERS VALUE ADDED	19.03000	22.40999	24.53000	26.64000	(DOLLARS)
13	PLASTICS SUPPLIERS EMPLOYMENT	0.00043	0.00064	0.00077	0.00090	(EMPLOYEES)
14	PLASTICS SUPPLIERS VALUE ADDED	2.12000	7.12000	10.20000	13.28000	(DOLLARS)
15	PAINT SUPPLIERS EMPLOYMENT	0.00071	0.00080	0.00084	0.00090	(EMPLOYEES)
16	PAINT SUPPLIERS VALUE ADDED	7.01000	8.98000	10.10000	11.3[illegible]000	(DOLLARS)
17	LEAD SUPPLIERS EMPLOYMENT	0.00025	0.00025	0.00026	0.00026	(EMPLOYEES)
18	LEAD SUPPLIERS VALUE ADDED	2.74000	2.90000	2.98000	3.05000	(DOLLARS)
19	COPPER SUPPLIERS EMPLOYMENT	0.00078	0.00083	0.00086	0.00091	(EMPLOYEES)
20	COPPER SUPPLIERS VALUE ADDED	8.37000	9.97000	10.86000	11.75000	(DOLLARS)
21	GLASS SUPPLIERS EMPLOYMENT	0.00262	0.00273	0.00278	0.00287	(EMPLOYEES)
22	GLASS SUPPLIERS VALUE ADDED	30.57999	33.35999	34.95999	36.53999	(DOLLARS)

The *1974 Buying Guide** and the *Automotive Industries, Almanac Edition*† were used to obtain the first two coefficients. They were derived by (1) averaging the price of the basic automobile and a selected group of options (power steering, power brakes, automatic transmission, tinted glass, air conditioner) of the four cars in each car class and (2) computing on the basis of the percentage of cars in each car class which have the options, the amount in dollars per car of options which the average car in each car class would consume. Some ambiguity might arise from the fact that manufacturers have the practice of designating certain items optional on some models and not on others. Another problem occurs when an item is made a "delete option"; that is, the consumer must request a car without the item. These factors

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* *1974 Buying Guide*, Consumers Union of the U.S., Inc., 1974, Mt. Vernon, N.Y.

† *Automotive Industries*, March 15, 1972, (Vol. 146, No. 6), 54th Annual Engineering Specifications and Statistical Issue, Chilton Publications,

produce the greatest disparity between the intermediate and full size car classes where full size cars tend to have a very low option cost because most of the optional items for smaller cars are standard in the full size car.

Dealers' employment due to new car sales was rather difficult to determine due to the numerous activities occurring in new car dealerships, i.e., servicing, used car sales, retail sales of parts, as well as new car sales. Based on figures obtained from the *1967 Census of Business*,[*] the average number of employees per dealership and average sales were computed. From *Automobile Facts and Figures*,[†] the number of new cars sold and the total number of cars sold were extracted. The average price per car sold could also be determined. Using these data, the employment per dealership per new car sold was calculated, assuming it proportional to the dollar amount of sales.

Dealers' sales margin should be analogous to value added for the suppliers, i.e., total sales less cost of materials. With regard to the sale of new cars alone, some good information exists in *The Automobile Industry Since 1955*.[‡] Information is available on absolute amounts of dealer discount given (list less wholesale price) and on Consumer Price Index figures showing the movement of price through the model year. Based on this information, a scale was constructed basing margin on the class of the car and this was used to compute the absolute margins based on the cost of the average car (basic cost + options) for each class.

Manufacturer's Employment per car was computed by using the *1972 Census of Manufactures*[¶] and *Automobile Facts and Figures*.[**] The first reference

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[*] *1967 Census of Business*, Bureau of the Census, U.S. Department of Commerce, Washington, D.C.

[†] *Automobile Facts and Figures* (annual). Motor Vehicle Manufacturers Association, Detroit, Michigan.

[‡] White, Lawrence J., *The Automotive Industry Since 1955*. Cambridge, Harvard University Press, 1971.

[¶] *1972 Census of Manufactures*. Bureau of the Census, U.S. Department of Commerce, Washington, D.C.

[**] *Automobile Facts and Figures*. Motor Vehicle Manufacturers Association, Detroit, Michigan

gives the employment for all manufacturers. This is divided by the number of passenger cars produced in that year to obtain employment per car. In order to compute the value added, the *1967 Input Output Structure of the U.S. Economy*[*] was used. Again, listed by SIC code, manufacturer's value added per dollar of output is simply computed. By multiplying that figure by the wholesale price of the automobile (list - dealer's margin), one gets *value added per car*.

The computation of *employment and value added for the suppliers* is slightly more difficult but conceptually quite simple. Sources used which provided information on material consumption are referenced below.[†,‡,¶,**,#]

A basic assumption was made with regard to employment. In the case of Dealers and Manufacturer employment, no weight effect was assumed. In fact in conversations with the UAW and manufacturers, little information was available and opinion seemed to be that the same number of man-hours were spent in assembling small and large cars. On the other hand, material consumption can be related to weight and it seems reasonable to attach employment and value added to that consumption. The assumption made, therefore, is that the amount of value added per car is directly proportional to the amount of material consumed in the car, and secondly that the amount of labor per car is half as sensitive to the amount of material. The latter assumption tries to take account of fabrication time which cannot be reduced.

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[*] *The 1967 Input-Output Structure of the U.S. Economy*. Bureau of Economic Analysis, U.S. Department of Commerce, Washington, D.C. 1974.

[†] *The 1967 Census of Manufactures, Materials Consumed*. Bureau of the Census, U.S. Department of Commerce, Washington 1972.

[‡] *Automobile Facts and Figures*. Motor Vehicle Manufacturers Association, Detroit, annual.

[¶] Hoffman, G., *Automobiles - Today and Tomorrow*. The RAND Corporation, Santa Monica, 1962.

[**] Haney and Menchen, *The Automobile - Energy and the Environment*. Hittman Associates, Columbia, Md., 1974.

[#] *The Automobile Cycle - An Environmental and Resource Reclamation Problem*. Environmental Protection Agency, Washington, 1972.

First, the amount of each type of material is graphed against car weight. Next, that amount is expressed as the amount in a car in each car class divided by the amount in an "average" car. (For the problem this was chosen to be the rough arithmetic average of the four car classes, 3400 lbs). With this information, plus an estimate of the average wholesale price of a passenger car in 1974, $2800 (average of consumer cost less dealer margin), the relative dollar level per car can be calculated. Of course, this number would only apply if the car were made entirely out of that material. To find the proportion of that material which goes into each car on a dollar basis, one looks in the *Input-Output* study.* For each supplier, the amount of his production as a portion of the total inputs is calculated. The amount of value added per dollar is also computed. Multiplying these factors together, (value added per dollar, proportion of inputs, and relative level of consumption) yields our estimate of *value added per car*.

Employment per car is calculated in a similar manner. The relative differences are halved in accordance with the assumption that employment is less sensitive than value added to changes in consumption. From the *Census of Manufactures*† one can get total employment and by using the *Input-Output** information one can determine the amount of production going to the automobile manufacturers. By dividing that portion of the industriy's employment by the total number of cars produced, we get an average figure of employment per car. By using the weighting function described above, a figure of employment per car by class can be reached.

The accuracy of the coefficients derived for the 22 societal elements is affected by at least two factors. Data from the several sources were sometimes inconsistent, requiring careful judgment. Some of the simplifying assumptions made in the computation process, while necessary, by their nature produce only approximate results.

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* *The 1967 Input-Output Structure of the U.S. Economy*. Bureau of Economic Analysis, U.S. Department of Commerce, Washington, D.C. 1974.

† *The 1967 Census of Manufactures*. Bureau of the Census, U.S. Department of Commerce, Washington, D.C.

APPENDIX F

DATA BASE FOR THE CAR OPERATIONS MODEL

F-1. ENGINE EFFICIENCY

In order to account for the decline of engine efficiency with age, it was assumed that the decrease in efficiency amounted to 10% over the life of the car and was incurred at a regular rate of 1% per year. The resultant efficiencies are shown in Table F-1.

TABLE F-1

ENGINE EFFICIENCY AS A FUNCTION OF CAR AGE

Efficiency (%)	Age of Car (Years Old)
100	0
99	1
98	2
97	3
96	4
95	5
94	6
93	7
92	8
91	9
90	10 and older

F-2. MARKET SHARES

Market Shares for the Car Operations Model are similar to the Market Shares used in the Accident and Car Sales Models. The Car Operations Model, however, requires Market Shares from 1975 through 1985. For purposes of simplicity and comparability with the other models, it was assumed that 1965-1974 Market Shares are the same as the 1975 Market Shares. The Car Operations Model was initially designed to accept input for 16 car types. For most analyses,Market Shares were input to the model in four car classes. For these analyses, the Market Shares in a given car class are divided equally among the four car types within the car class.

F-3. NUMBER OF REGISTERED CARS

As discussed in Section D-2 of Appendix D, the car population consists of the actual registrations from 1965 through 1973 and the projected population from 1974 through 1985.

F-4. GASOLINE COST PER MILE

The gasoline cost per mile was derived on the basis of the 1974 EPA economy lists* and the assumption of a gasoline cost of 50¢ per gallon. It seems apparent in view of recently released data, that the 1974 gasoline consumption figures reflect the emission controls requirement to a greater degree than the factor of car weight. Since this information was not available prior to preparation of the data base, the gasoline consumption data give a non-representative picture of the gas economy of intermediate size cars. The factors presented in Table F-2 were derived by taking the reciprocal of the average gas economy for the 16 cars in the study and multiplying by the price. For some car types, data for only one or two cars were available; data for other car types were ample. Hence, the figures given in Table F-2 vary in reliability.

TABLE F-2

GASOLINE CONSUMPTION FOR 16 CAR TYPES

Model	($ Cost/Mile)
1. Bat	0.0217
2. Alba	0.0227
3. Chee Sai	0.0217
4. Mini	0.0238
5. Gnone	0.0333
6. Musketeer	0.0333
7. Beacon	0.0322
8. Libre	0.0333
9. Diadem	0.0454
10. Oriole	0.0555
11. Machete	0.050
12. Alladin	0.050
13. Condor	0.0454
14. Hastings	0.0476
15. Taurus	0.0526
16. Ocelot	0.0555

***Control of Air Pollution from New Motor Vehicles and Engines*, Environmental Protection Agency, Washington, D.C., 1973.

F-5. AVERAGE CAR MILEAGE BY AGE OF CAR

This information in Table F-3 is taken directly from a figure entitled, "Average Annual Miles per Vehicle by Year-Model of Automobile" in the *Nationwide Personal Transportation Survey.**

TABLE F-3

VEHICLE MILEAGE BY CAR AGE

Age of Car	Average Annual Miles
0-1	17,500
1-2	16,100
2-3	13,200
3-4	11,400
4-5	11,700
5-6	10,000
6-7	10,300
7-8	8,600
8-9	10,900
9-10	8,000
10-older	6,500

F-6. CRASH REPAIR COSTS PER YEAR PER CAR

Coefficients that were derived are based on the previous reference and on material in *Automobile Insurance Losses.*† Based on the information on claim frequency (accidents per vehicle years) and average loss payments, it was possible to calculate the average loss payment per vehicle year for each of the four car classes. Since these data were based on the latest full model year data and making the reasonable assumption that accident experience follows exposure, one can then predict the average loss payments through the life of the car, based on the amount of annual travel. The crash repair costs per year per car are given for 16 car types and 11 car age categories in Table F-4.

**Nationwide Personal Transportation Survey - Report No. 2 - Annual Miles of Automobile Travel*, Federal Highway Administration, U.S. Dept. of Transportation, Washington, D.C., 1972.

†*Automobile Insurance Losses Collision Coverages - Variations by Make and Series*, Highway Loss Data Institute, Washington, D.C., 1973 and 1974.

TABLE F-4

CRASH REPAIR COSTS PER YEAR PER CAR ($)

Car Type	Age of Car (Years)										
	0	1	2	3	4	5	6	7	8	9	10 or More
1-4	85	78	64	56	57	49	50	42	54	40	31
5-8	72	66	54	67	48	41	42	35	45	33	26
9-12	75	69	57	50	50	43	44	37	47	35	28
13-16	64	59	48	42	43	37	38	31	41	30	24

F-7. ROUTINE MAINTENANCE AND REPAIR COSTS

A variety of material was utilized in deriving routine maintenance and repair costs but the principal sources were *Cost of Operating an Automobile*[*] and *Consumer Reports*, "Frequency-of-Repair Records, 1970-1973."[†]

The first reference gave Routine Maintenance and Repair Costs for Subcompacts, Compacts and Full Size vehicles over a 10-year life span. The second reference provided a basis for differentiating between the four car types within a car class to determine whether they were better or worse than average (a 5% variation within class was applied). In the case of the Intermediate class, the simple average of the Compact and Full Size costs were taken. The routine maintenance and repair costs are given for 16 car types and 11 car age categories in Table F-5.

[*] *Cost of Operating an Automobile*, Federal Highway Administration, U.S. Dept. of Transportation, Washington, D.C., 1972.

[†] *1974 Buying Guide*, Consumers Union of the U.S., Inc., Mt. Vernon, N.Y., 1974.

TABLE F-5

ROUTINE MAINTENANCE AND REPAIR COSTS PER YEAR PER CAR ($)

Car Type	Age of Car (Years)									
	0	1	2	3	4	5	6	7	8	9	10 or More
1	75	102	162	208	228	255	391	168	75	30	30
2	83	113	179	230	252	282	433	186	83	33	33
3	83	113	179	230	252	282	433	186	83	33	33
4	83	113	179	230	252	282	433	186	83	33	33
5	79	107	171	219	240	269	412	177	79	31	31
6	75	102	162	208	228	255	391	168	75	30	30
7	83	113	179	230	252	232	433	186	83	33	33
8	83	113	179	230	252	282	433	186	88	33	33
9	85	117	222	265	270	295	425	183	170	32	32
10	81	111	212	253	257	281	405	175	162	30	30
11	77	106	201	240	245	267	385	166	154	29	29
12	81	111	212	253	257	281	405	175	162	30	30
13	86	121	255	311	289	307	417	180	257	31	31
14	78	110	231	281	262	278	378	163	232	28	28
15	86	121	255	311	289	307	417	180	257	31	31
16	78	110	231	281	262	278	378	163	232	28	28

F-7. INSURANCE: COLLISION AND LIABILITY

An implicit assumption in this portion of the model is that all drivers obtain insurance. In order to make the total expense realistic, the total national amount for insurance costs was distributed over all passenger cars. Data were collected from the State of Connecticut's Insurance Commission,[*] from *Insurance Facts and Figures*,[†] and *Automobile Facts and Figures*.[‡] It was

[*] Insurance data on file at the State of Connecticut's Insurance Commission.

[†] *Insurance Facts and Figures*, Insurance Information Institute, New York.

[‡] *Automobile Facts and Figures*, Motor Vehicle Manufacturers Association, Detroit, Michigan, annual.

assumed that collision insurance was discontinued after a car was six years old. The calculation of the *collision insurance* was fairly straightforward once it was discovered that the majority of insurance companies discount the insurance at the same rate over time. The problem was confined to setting the initial value of the premium. Premiums for cars less than one year old were plotted against the value of the car and a simple linear curve could be approximated. Thus, the initial premiums could be estimated for each car type. In the case of *liability insurance,* it was found in *Motor Vehicle Crash Losses and Their Compensation in the United States** that only 85% of the cars had liability coverage. A review of several sources revealed that a rate of $150 per insured vehicle seemed indicated. However, due to our assumption that all cars are covered by liability insurance, it was necessary to reduce the rate to $120 per insured vehicle to fit the total national expense. The costs of insurance premiums are given for 16 car types and 11 car age categories in Table F-6.

TABLE F-6

INSURANCE COSTS PER YEAR PER CAR ($)

Car Type	Age of Car (Years)									
	0	1	2	3	4	5	6	7	8	9	10 or More
1-4	160	150	150	146	146	142	142	120	120	120	120
5-8	165	154	154	149	149	145	145	120	120	120	120
9-12	169	157	157	152	152	147	147	120	120	120	120
13-16	177	163	163	157	157	151	151	120	120	120	120

*J. A. Volpe, *Motor Vehicle Crash Losses and Their Compensation in the United States,* Dept. of Transportation, Washington, D.C., 1971.

APPENDIX G

PASSENGER CAR
FLEET BUYER STUDY

G-1. BACKGROUND

Vehicle fleet buyers purchase between 10-20% of each year's automobile production. They not only represent a sizable share of the new model year market, but the purchasing decisions made are more than likely based on a more quantitative rationale for the market as a whole. If true, the impact of Title II may be quite different (possibly greater) than on individual automobile buyers. To assess this (and to determine other aspects of fleet buyers), CEM developed a short questionnaire which was submitted to nine* (9) fleet buyers representing the following fields:

1. Municipal government - 2
2. Utilities - 3
3. Other private companies - 4

Questionnaires were sent out and returned in the fall of 1974.

G-2. CHARACTERISTICS OF THE FLEETS SAMPLED

Overall, 18,868 passenger cars were included in the nine fleets. Individual fleet volumes per company ranged from 325 to 5363. New cars (1974 models) represented about 38% of the total sample. On a company basis, new model purchases ranged from less than 1% to 100%. New car purchases for the entire sample were made as follows:

1. Full size - 15%
2. Intermediate - 60%
3. Compacts - 20%
4. Subcompacts - 5%

For the 1975 model year, 75% of the fleet buyers predicted that purchasing volumes would change. Of these, two-thirds indicated that the 1975 model year volume would be reduced 46% (range: 30-80%) compared to the 1974 model year, while the other one-third predicted an increase in volume of 30% (range: 10-50%) compared to the 1974 model year.

Slightly more than half (55%) of the respondents indicated they would change the <u>size</u> of the 1975 model. Table 1 summarizes these changes for each weight group and compares the overall new car purchasing predictions (1975 model year) with actual 1974 model year purchases. For all nine fleets, 16% fewer new car models will be bought. While <u>no change in the subcompact class</u> is to be expected, the predictions suggest an:

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*Limit set to comply with NHTSA requirements.

1. 18% <u>increase</u> in compact cars,
2. 11% <u>decrease</u> in intermediates, and
3. 88% <u>decrease</u> in full-size or standard models.

In general, the between class shifts typically went from the higher to lower weight groups. Combining both effects (e.g., purchasing volume and between class shifts), the 1975 models bought by the fleets represented in this sample will be comprised approximately as follows:

- Full size - 2%
- Intermediates - 63%
- Compacts - 28%
- Subcompacts - 6%

TABLE G-1

SHIFTS IN NEW CAR PURCHASES
(1974 vs. 1975 Models)

Number and % of 1974 Models Purchased		No. and % of 1975 Models "Purchased" (predicted)				
		Sub Compact	Compact	Inter-mediate	Full Size	
Sub Compact	350 (5)	350				
Compact	1435 (20)		1430			
Inter-mediate	4208 (60)		262	3232		
Full Size	1088 (15)			540	134	
Total 1974	7081 (100)	350 (6)	1692 (28)	3772 (63)	134 (2)	Total 1975 5948 (100)
Net Change: '75 vs. '74 Models		None	+18%	-11%	-88%	-16%

Fleet cars in our sample are replaced on the average every 4.25 years or 62,500 miles. New cars are typically individually bought (or leased) as needed from local dealers <u>or</u> bought (or leased) in large lot sizes generally of the same make/model per order.

In buying new models, fleet purchasers almost always specify:

- Vehicle size class (compact, intermediate, etc.)
- Body style, and
- Engine size,

but almost never, number of doors or trunk size.

Depending upon the company, most vehicle operators have limited (or no) choice in selecting vehicle makes or models.

Equipment options were specified by the operator in nearly half (48%) of the 1974 models bought by fleets. Options typically selected include:

- Power disc brakes
- Power steering
- Automatic transmission
- Air conditioning
- AM pushbutton radio
- Non-standard colors

Radial tires, bumper guards and tinted windows are selected by about one-third of the buyers for all cars and are definitely options considered for executive (and other) models. On the other hand, a high performance engine is rarely selected for fleet vehicles

Sixteen car features important to fleet buyers were ranked in terms of importance to the purchasing decision. Table 2 (below) summarizes the rank using a 10-point scale (1 highest; 10 lowest).

TABLE G-2

RELATIVE CONTRIBUTION OF SELECTED CAR FEATURES TO THE FLEET PURCHASING DECISION

Car Feature	Rank
- Safety & protection of occupants	1
- Car price, gas economy; reliability	2
- Availability/quality of service; vehicle responsiveness	3
- Dealer reputation	4
- Manufacturer's warranty	5
- Brand name/reputation; re-sale or trade-in value	6
- Solidness of construction	7
- Roominess; power & pickup; styling and appearance	8
- Riding comfort	9
- Prestige	10

Information sources used most frequently in planning a new model year purchase include:

- Manufacturer's brochures and automotive magazines
  - both extremely helpful to the decision-maker;
- Official used car guides
  - used often and quite helpful;
- Own mechanics or repair garage personnel
  - used often and quite helpful;
- Personal experience of purchaser
  - often used and quite helpful;
- Feedback from operators
  - used now and then, often helpful.

Government brochures (e.g., booklets on braking distance) appear to be used only now and then and are apparently only slightly helpful. Consumer magazines are used for reference by about one-third of the respondents - but only occasionally; most agreed that these are not very helpful in the purchasing decision.

Nearly 90% of the fleets are self-insured for collision coverage while auto-medical coverage is either obtained via workmen's compensation or through a self-insured package. Less than one-third of the fleets obtained medical insurance on a low bid basis. "Bumper and air bag availability discounts" were offered to one out of six fleets. Had the insurance industry made such discounts more available to fleet insureds, "air bag discounts" would have been chosen by one-third of the fleets; on the other hand, "bumper discounts" would have been selected by only 17% of the fleets.

To determine the relationship between insurance premium discount and purchase price increase per car, we asked fleet respondents to specify for each insurance premium discount (from $0 to $50 per car per year), how much more they would be willing to spend (in terms of purchase price) to still consider a given car for their fleet. Two fleets provided responses as follows:

Respondent #1 indicated he would be willing to spend:

- $50 more per car if the insurance premium discount were $10 less per car per year;
- $100 more per car if the discount were $20 less per car per year;
- $200 more per car if the discount were $50 less per car per year.

Respondent #1 acted reasonably rationally for each premium discount level, since he will "recover" his purchase price increase during the average 4.25 years the car is kept in the fleet.

Respondent #2 indicated he would be willing to increase his purchase price by:

- As much as $200 per car if the insurance premium discount were only $10 less per car per year. Thus, if he kept his cars in the fleet an average of four years, he would "recover" only 20% of his original purchase differential. On the basis of this information and his other responses, we suspect that this respondent was not rational in his selection process.

Of the remainder, four fleets do not consider such information in their purchasing decision, while three left this question blank.

G-3. POSSIBLE EFFECTS OF TITLE II INFORMATION ON FLEET PURCHASING DECISIONS

To assess how information on crashworthiness, crash damage susceptibility and preventive maintenance and routine repair cost might affect fleet buyers, quantitative estimates were provided for each information category (for each vehicle and/or vehicle size class). Respondents were then asked whether (on the basis of the information provided) they would:

1. Stay with the same make/model
2. Switch to another vehicle in the same size class
3. Switch to another vehicle in another size class
4. Switch to another vehicle without changing the purchase price, or
5. Switch to another vehicle and change the purchase price.

Tables 3 and 4 illustrate the information* for the compact and intermediate size class buyers.

*Graphical displays were also presented to see if the information format influenced the purchasing decision; however, no effect was found.

TABLE G-3

ESTIMATES OF TITLE II INFORMATION FOR COMPACT CAR CLASS BUYERS

Vehicle Class	*Crashworthiness*	*Damage Susceptibility*	*Ease of Diagnosis and Repair*
	Percent Fatal or Serious Injury per Crash (%)	Average Repair Cost per Accident ($)	Average Repair & Maintenance Cost per year ($)
Subcompacts	7.1 - 8.5	480 - 535	170 - 210
Compacts	5.0 - 6.9	470 - 555	185 - 240
Gnome	6.9	555	190
Beacon	5.0	510	185
Libra	6.5	470	240
Musketeer	6.2	530	215
Intermediates	3.5 - 6.0	480 - 565	195 - 250
Full Size	2.8 - 4.9	480 - 560	235 - 275

TABLE G-4

ESTIMATES OF TITLE II INFORMATION FOR INTERMEDIATE CAR CLASS BUYERS

Vehicle Class	*Crashworthiness*	*Damage Susceptibility*	*Ease of Diagnosis and Repair*
	Percent Fatal or Serious Injury per Crash (%)	Average Repair Cost per Accident ($)	Average Repair & Maintenance Cost per Year ($)
Subcompacts	7.1 - 8.5	480 - 535	170 - 210
Compacts	5.0 - 6.9	470 - 555	185 - 240
Intermediates	3.5 - 6.0	480 - 565	195 - 250
Machete	3.5	565	245
Aladdin	4.2	515	250
Oriole	5.0	520	195
Diadem	6.0	480	230
Full Size	2.8 - 4.9	480 - 560	235 - 275

Table 5 summarizes the effect of Title II information for seven fleets typically buying Musketeers (compacts) before Title II information was available. Based on the information:

- Nearly 30% indicated they would continue to buy Musketeers;
- Slightly more than 40% said they would switch to the Beacon (another compact) without changing purchase price;
- The rest (30%) would also switch to the Beacon and (each) allow a $100 increase in purchase price.

TABLE G-5

POTENTIAL EFFECT OF TITLE II INFORMATION ON FLEET COMPACT CAR BUYERS

BEFORE TITLE II				
Compact Car Bought Before Title II	Crash-worthiness[1] (%)	Damage Suscept.[2] ($)	Ease of Diagnosis & Repair[3] ($)	No. of Fleets Buying Musketeers Before Title II
Musketeer	6.2	530	215	7
AFTER TITLE II				
Compact Car Shifted to After Title II				No. of Fleets Which Would Buy Compacts After Title II
Gnome	6.9	555	190	
Beacon	5.0	510	185	5[4]
Libra	6.5	470	530	
Musketeer	6.2	530	215	2

[1] Percent of fatal or serious injury per crash
[2] Average crash repair cost
[3] Average annual routine maintenance & repair cost

Title II information

[4] 3 fleets: no increase in purchase price;
2 fleets: $100 increase in purchase price.

Since the Beacon is overall the better car with respect to Title II characteristics, the availability of such information is apparently useful to 70% of the fleet. For the rest, the differences in injury risk (crashworthiness), crash damage and routine repair costs are possibly not large enough to influence a switch to the "better" car.

Table 6 compares the before and after Title II purchases for eight Oriole (intermediate car) buyers. The data suggest that:

- 75% of the original Oriole buyers would continue to buy Orioles after Title II information were available;
- The remainder would switch by trading off lower routine maintenance costs for lower injury risk (and slightly higher crash damage costs). Of these, one switched to the Machete (a heavy intermediate), at no increase in purchase price (thus, probably dropping some equipment options) while the other switched to the full size class and was willing to pay an additional $400 to do so for a higher crashworthiness rating.

TABLE G-6

POTENTIAL EFFECT OF TITLE II INFORMATION ON FLEET INTERMEDIATE CAR BUYERS

BEFORE TITLE II				
Intermediate Car Bought Before Title II	Crash-worthiness[1] (%)	Damage Suscept.[2] ($)	Ease of Diagnosis & Repair[3] ($)	No. of Fleets Buying Orioles Before Title II
Oriole	5.0	520	195	8
AFTER TITLE II				
Make/Model Shifter to After Title II				No. of Fleets Which Would Buy Make/Model After Title II
Machete	3.5	565	245	1[4]
Aladdin	4.2	515	250	
Oriole	5.0	520	480	6
Diadem	6.0	480	230	
Full-size Class	2.8-4.9	480-560	235-275	1[5]

[1] Percent of fatal or serious injury per crash

[2] Average crash repair cost

[3] Average annual routine maintenance & repair cost

[4] No change in purchase price

[5] $400 increase in purchase price

G-4. SUMMARY

Characteristics of nine passenger car fleets (about 19,000 cars) and their new car purchasing decisions were examined to obtain a rough estimate of how Title II information would affect future vehicle purchases.

Shifts in vehicle size (e.g., from intermediates to compacts, etc.) were examined without the influence of Title II information. The results suggest that substantially fewer full-size 1975 models may be bought (compared with 1974 models) while only slightly fewer intermediate models may be purchased. For the compact and subcompact classes, no change was predicted. Overall, 16% fewer 1975 models will be bought by the nine fleets compared with the 1974 model year. No reason was given for the reduction (and between class shifts) although we might suggest that the "energy crisis" had a strong influence.

The effect of Title II information was most noticeable for the make/model having the "best" overall Title II rating. For example, 70% of compact car (Musketeer) buyers switched to another compact (Beacon) which was:

- About 20% better in crashworthiness
- About 4% better in damage susceptibility, and
- About 14% better in routine maintenance and repair cost.

A weaker Title II effect was noted when only crashworthiness information was substantially different, e.g., of intermediate car buyers (Orioles), only 25% switched to the heavier (intermediate [Machete] and full size) cars which were:

- About 30% "better" in crashworthiness
- About 10% "worse" in damage susceptibility, and
- About 25-40% "worse" in routine maintenance and repair costs.

The remainder (75%) preferred to stay with their original choice, regardless (apparently) of Title II data.

APPENDIX H

IMPACT OF CAR WEIGHT

ON

RISK OF FATAL OR SERIOUS INJURY

For two-car crashes, let us use Mela's formula:*

$$R_{TC} = c \times 0.95^{w_a} \times 1.02^{w_b}$$

where

R_{TC} = Risk of a fatal or serious injury in a car of weight w_a that crashes with a car of weight w_b,

w_a, w_b = Weight (in hundreds of pounds) of the two cars in the crash

c = Constant of proportionality

Now let us define $\bar{w}$ as the average weight of the entire population of automobiles.

A term like 1.02^{w_b} can be expanded as follows:

$$1.02^{w_b} = 1.02^{\bar{w}} \times 1.02^{w_b - \bar{w}}$$

$$= 1.02^{\bar{w}} [1 + 0.02(w_b - \bar{w}) + \text{Higher order terms, which are neglected}]$$

where we have used the Binomial Theorem to expand:

$$1.02^{w_b - \bar{w}} = (1 + 0.02)^{w_b - \bar{w}}$$

We now neglect higher order terms in the expansion and re-write the expression for R_{TC}:

$$R_{TC} = c \times 0.95^{w_a} \times 1.02^{\bar{w}} [1 + 0.02(w_b - \bar{w})]$$

Define a function of w_a and $\bar{w}$ to be:

$$D(w_a, \bar{w}) = c \times 0.95^{w_a} \times 1.02^{\bar{w}}$$

then,

$$R_{TC} = D(w_a, \bar{w}) \times [1 + 0.02(w_b - \bar{w})]$$

Now let us assume that a car of weight w_a collides with cars of weights $w_1, w_2, w_3, \ldots w_n$ with probabilities $p_1, p_2, p_3 \ldots p_n$ and $p_1 + p_2 + p_3 + \ldots + p_n = 1.0$. Then the average risk for occupants of car w_a, averaged over the other cars it collides with, is

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*See page 48-17 in <u>*How Safe Can We Be in Small Cars*</u>, by Don Mela, published in the *Proceedings of the Third International Congress on Automotive Safety*, Vol. II, July 15-17, 1974, San Francisco, California.

$$R_{TC}(w_a) = D(w_a,\overline{w}) \times \left\{1 + 0.02[(w_1-\overline{w})p_1 + \ldots + (w_n-\overline{w})p_n]\right\}$$

But,

$$w_1p_1 + w\ldots + w_np_n \cong \overline{w}$$

(This would be exact, if the car population was composed only of cars of exactly weights $w_1,\ldots w_n$ and all weight classes had the same exposure.)

Also, $\overline{w}\,(p_1 + \ldots + p_n) = \overline{w}$

because the summed probabilities equal 1.0.

Therefore, the term in square brackets is essentially zero, and will be neglected,

Thus,

$$R_{TC}(w_a) = D(w_a, \overline{w}) = c \times 0.95^{w_a} \times 1.02^{\overline{w}}$$

Now we will assume that the average weight of all cars in the population changes relative to a "baseline" ($\overline{w}_B$) by an incremental amount

$\Delta\overline{w}$ (where $\Delta\overline{w}$ is in hundreds of lb). That is:

$$\overline{w} = \overline{w}_B + \Delta\overline{w}$$

Then the term involving $\overline{w}$ in the above expression for risk can be written

$$1.02^{\overline{w}} = 1.02^{\overline{w}_B} \times 1.02^{\Delta\overline{w}} = 1.02^{\overline{w}_B} \times (1 + 0.02)^{\Delta\overline{w}}$$

$$= 1.02^{\overline{w}_B}(1 + 0.02\Delta\overline{w})$$

where we have again used the first two terms of the Binomial Expansion by assuming that all higher order terms are small for small $\Delta\overline{w}$ (i.e., for changes in average weight of a few hundred pounds).

Therefore,

$$\boxed{R_{TC}^{(\overline{w}_a)} = c \times 0.95^{w_a} \times 1.02^{\overline{w}_B} (1 + 0.02\Delta\overline{w})}$$

Now we go to another topic. Let $R_1(w_a)$ be the risk in car of weight w_a in a single car crash. Let g be the fraction of cars in crashes that are two-car crashes, and (1-g) be the fraction in single-car crashes; (we will assume all multiple-car crashes are two-car crashes).

Then, the overall risk in the car of weight w_a is

$$R(w_a) = \begin{bmatrix}\text{Risk of incurring a FOSI} \\ \text{in a two-car crash}\end{bmatrix} + \begin{bmatrix}\text{Risk of incurring a FOSI} \\ \text{in a single-car crash}\end{bmatrix}$$

$$= gxR_{TC}(w_a) + (1-g)xR_1(w_a)$$

$$= gxC \times 0.95^{w_a} \times 1.02^{\bar{w}_B}(1 + 0.02\Delta w) + (1-g)\ R_1(w_a)$$

We can expand this into three terms:

$$R(w_a) = [gxCx0.95^{w_a} \times 1.02^{\bar{w}_b}] + [gxC \times 0.95^{w_a} \times 1.02^{\bar{w}_b}]\ 0.02\Delta\bar{w} + (1-g)R_1(w_a)$$

For the baseline car population ($\Delta\bar{w} = 0$), the first and last terms have been shown to be approximately equal. That is, the FOSI in single car crashes is approximately equal to the FOSI in two-car crashes. Let us define for the baseline car population:

$$R_{TC_B} \triangleq g \times c \times 0.95^{w_a} \times 1.02^{\bar{w}_b}$$

Then, because single-car crash and two-car crash FOSI are essentially equal:

$$R_{TC_B} = (1-g) \times R_1(w_a)$$

and

$$R_B(w_a) = 2\ R_{TC_B} \qquad \text{or,}\ R_{TC_B} = \frac{R_B(w_a)}{2}$$

where $R_B(w_a)$ is the risk of incurring a FOSI in a crash before the weight change (i.e., $\Delta\bar{w} = 0$).

Hence, going back to our above expression with three terms:

$$R(w_a) = R_{TC_B} + R_{TC_B}[0.02\Delta\bar{w}] + R_{TC_B}$$

$$= R_{TC_B}\ [2 + 0.02\Delta\bar{w}]$$

$$= \frac{R_B(w_a)}{2}\ [2 + 0.02\Delta\bar{w}]$$

or

$$R(w_a) = R_B(w_a)\left[1 + \frac{\Delta\bar{w}}{100}\right]$$

Thus, we have shown that to a first approximation the risk of incurring a FOSI in a car crash, after the average weight of the car population has changed relative to the baseline population, is simply:

$$\boxed{R_{new} = R_{old}\left[1 + \frac{\Delta\bar{w}}{100}\right]}$$

Note:

It is important to keep in mind that the assumption that FOSI in single-car crashes is equal to FOSI in two-car crashes is not vital to this argument. We need merely have a constant relationship. For example, suppose 40% of all FOSI occur in single-car crashes, and 60% of all FOSI occur in two-car crashes. Then, for the baseline car population:

$$R_{TC_B} = 0.6 \text{ (Overall risk of incurring a FOSI)}$$

$$(1-g)R_1(w_a) = 0.4 \text{ (Overall risk of incurring a FOSI)}$$

Hence,

$$\frac{R_{TC_B}}{0.6} = \frac{(1-g)R_1(w_a)}{0.4}$$

$$1.5\ R_{TC_B} = (1-g)R_1(w_a)$$

and

$$R_B(w_a) = R_{TC_B} + 1.5\ R_{TC_B} = 2.5\ R_{TC_B}$$

or $$R_{TC_B} = \frac{R_B(w_a)}{2.5}$$

Going back to our original expression for $R(w_a)$, we have

$$R(w_a) = R_{TC_B} + R_{TC_B}[0.02\Delta\bar{w}] + 1.5R_{TC_B}$$

$$= R_{TC_B}[2.5 + 0.02\Delta\bar{w}]$$

$$= \frac{R_B(w_a)}{2.5}[2.5 + 0.02\ \Delta\bar{w}]$$

$$= R_B(w_a)\ [1 + 0.008\Delta\bar{w}]$$

or,

$$\boxed{R_{new} = R_{old}[1 + 0.008\Delta\bar{w}]}$$

if the ratio of [FOSI in two-car crashes]/[FOSI in single-car crashes] = 1.5. Obviously, the same procedure can be followed for any other ratio. The general expression would become:

$$R_{new} = R_{old} \left[1 + \frac{0.02\Delta\bar{w}}{\left[1 + \frac{R_{TC_B}}{R_{SC_B}} \right]} \right]$$

where

R_{TC_B} = Risk of incurring a FOSI in a two-car crash, using the baseline car population

R_{SC_B} = Risk of incurring a FOSI in a single-car crash, using the baseline car population